A STUDY OF THE CONNECTIVITY BETWEEN THE DEFENSE LABORATORIES, INDUSTRY, AND ACADEMIA IN THE AREA OF INFORMATION TECHNOLOGY

By Dr. Alan Berman

for

The Center for Technology and National Security Policy
National Defense University

Washington, D.C.

July 2003

[*Revised April 2004*]

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUL 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
A Study of the Connectivity Between The Defense Laboratories, Industry, and Academia in the Area of Information Technology	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Center for Technology and National Security Policy,National Defense University,Washington,DC**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**69**	

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In FY 2002, Congress noted that the "Department of Defense can no longer depend on a dedicated defense industrial base, but will need to find ways to link advanced commercial technologies to improved military capabilities." The Defense Appropriations committee, in PE 65104D8Z, funded the Center for Technology and National Policy Studies (CTNSP) at the National Defense University (NDU) to develop a pilot program "to find practical ways in which the defense information technology community can gain a mutual understanding of defense needs and industry capabilities and identify opportunities to integrate information technology innovations into the U.S. military strategy."

To address this issue, the CTNSP program implemented a number of efforts. One initiative was to commission a study by Dr. Alan Berman to assess the current status of the Department of Defense (DoD) Laboratories' work in Information Technology (IT) and the status of their relationship with the IT industry. Mr. Don DeYoung, a Senior Research Fellow at the CTNSP, assisted in the conduct of Dr. Berman's review and in the writing of the report. Together they constituted what will hereafter be referred to in this report as the Study Team.[1]

According to their charter, the Study Team was tasked to:

> "Assess the current status of the Department of Defense Laboratories' work in Information Technology and the status of their relationship with the IT industry. Specific attention will be focused on the extent of the laboratories' collaborations with commercial IT companies. If the scale /and or quality of the collaborations prove to be inadequate, then the impediments will be identified along with specific recommendations on how to remove them."

The scope of this review was later expanded to include their relationship with both academia and other DoD laboratories. As indicated in the body and appendices of this report, the work of DoD Laboratories in the area of Information Technology is at the forefront of professional activity. Although significant variability exists amongst the DoD IT Laboratories in the level and types of interactions with the IT industry and IT developments in Academia, the interactions are generally strong and healthy.

Based on the findings of the Study Team, the scale and quality of collaborations between the DoD IT laboratories and the IT industry appear to be adequate. Many mechanisms are available to implement such interactions. Although some technical and legal impediments to interactions between DoD laboratories and industry were identified, industrial and laboratory management are able to find ways to work around the situation.

Such impediments as were discovered, (e.g. 10 U.S.C § 2563 "Sales of Articles or Services" agreements which permits industry to hire a DoD Laboratory as a sub-contractor, but does not permit industry to sue for redress in the event of inadequate performance by a DoD laboratory)

[1] In April 2004, this study was revised to incorporate observations made by Dr. John Lyons, a Distinguished Fellow at NDU's Center for Technology and National Security Policy.

do not warrant remedial action. Expedients are available that obviate the problem. Roles may be reversed where the Laboratory can become the prime and the industrial member of the consortium can become the sub-contractor. Alternatively, fees can be (and have been) built into contracts to cover the possible costs to an industrial contractor when a DoD Laboratory sub-contractor does not perform as required in the contract.

The Study Team was impressed by the variety of techniques and methods employed by the different laboratories it visited. The means of choice for interacting with the IT industry is very much a function of the nature of work of each Laboratory, its perception of its mission and its sources of funding. Ultimately the Laboratories at some point all employ the same techniques to foster interactions with Industry and Academia. However, each Laboratory makes differential use of the totality of options that are available to it.

The modes of interaction found by the Study Team included:

- Cooperative Research and Development Agreements (CRADA)
- Sponsor directed joint activities with industry or academia
- Service as Contracting Officer's Technical Represent (COTR) for IT R&D contracts with industry and academia
- Contractual relationship (Industry or academic organization works for DoD IT laboratory under contract)
- DoD IT Laboratory serves as contract monitor or agent for the Office of Naval Research (ONR) or the Defense Advanced Research Projects Agency (DARPA) to oversee / manage R&D activity with industrial or academic performing organization.
- 10 U.S.C.2563 "Sales of Articles or Services" agreements with industrial funding of DoD IT laboratories by industrial sponsors
- Faculty Sabbaticals or summer employment
- Licensing and royalty agreements
- Joint authorship of papers submitted to refereed journals
- Direct support of graduate student research (Salary and facility support)
- NRC/NAS/NAE Post-Doc programs
- Specialized local area Partnerships (e.g. Center for Commercialization of Advance Technology (CCAT))
- Membership in State or University sponsored consortia (e.g. California Institute for Telecommunications and Information Technologies (CAL (IT) ^{2})
- Ad Hoc professional relationships between Laboratory staff members and their peers in industry and academia
- Community Interactions (Service by DoD IT Laboratory staff members on University, FCRC, Professional Society and Community advisory boards and Panels)

The Study Team found that the forgoing list is not exhaustive of the modes of "Interaction" that exist. All of the organizations reviewed by the Study Team could claim that to one degree or another that they used all of these modes of interaction.

On the other hand, the staff of Marine Corps Warfighting Laboratory (MCWL) is constrained to engage in a limited set of activities in support of Marine Corps needs. Predictably, members of

MCWL's staff have more limited professional interactions with the external IT community than do staff members at the other DoD IT laboratories. The management of the other four laboratories that the Study Team visited is justifiably proud of the professional interactions and the positions of influence that members of their staff hold in the worldwide IT community. Such personnel serve on industry standards committees, on professional society working groups, on editorial boards of professional society journals, etc. To the extent that the Laboratories serve as S&T funding agencies, as research sponsors or as agents of research sponsors, it is hard to imagine any industrial or academic IT organization of any significance that does not interact with the DoD IT Laboratories.

The following are some recommendations made by the Study Team:

1. DoD should submit an annual report to Congress that summarizes the extensive nature of the entire range of interactions of DoD IT Laboratories with Industry and Academia. This report should be given broad dissemination and should be highlighted, as one of the significant contributions of these organizations, to the continuing development of the Nation's Information Technology infrastructure.

2. The Ad Hoc nature of the multiplicity of interactions that were discussed in this report should be institutionalized by a system of rewards and incentives. Among the rewards and incentives that should be considered are:

    - Financial awards and or other recognition for DoD employees who serve as co-authors of publications with colleagues affiliated with industrial or academic organizations.

    - The establishment of a designated overhead account that may be used to charge activities of DoD IT Laboratory personnel in support of national professional IT societies and standards setting panels.

    - Annual performance evaluation factors of senior DoD IT Laboratory managers should include activities that have resulted in demonstrable improvements in the interactions between their organizations and IT organizations in Industry and Academia

3. Agencies (DARPA, ONR. AFOSR, ARO) that sponsor IT S&T activities in DOD Laboratories, should be directed to designate a small fixed percentage of the funds that they transfer to the DoD IT Laboratories for exclusive use as seed money for the development and support of new interactions with Industrial and Academic IT organizations.

4. When setting up external centers of excellence for collaboration, the military laboratories should:

    - Select the topical areas through a careful assessment of internal strengths and weaknesses.

    - Build external capability through consortia of academe and industry rather than individual firms or schools.

- Make certain the internal matching strengths are well supported.

- Manage the internal and external efforts as a single program. (Use new procurement authorities.)

- Require agreement as to the movement of staff back-and-forth.

In conclusion, the Study Team would like to underscore the importance to the military of having internal expertise to link to its external collaborators. Study after study have argued for having this internal capability so as to be able to advise senior leadership on acquisition decisions – the "smart buyer" role. We believe this means more than program managers but rather staff working in the internal laboratories on the same class of problems. In recent years we have also learned that the transition of new technology from one entity to another goes best when staff from both sides have worked on the problem in the laboratory in a collaborative manner. Indeed in some cases the staff actually moves with the technology. Within the scope of this study, the best examples of how to do this are at the NRL, as discussed in the previous section. We conclude that the other service laboratories keep this model in mind as they go about creating external links to needed expertise.

1. BACKGOUND

In FY 2002, Congress noted that the "Department of Defense can no longer depend on a dedicated defense industrial base, but will need to find ways to link advanced commercial technologies to improved military capabilities." The Defense Appropriations committee, in PE 65104D8Z, funded the Center for Technology and National Policy Studies (CTNSP) at the National Defense University (NDU) to develop a pilot program "to find practical ways in which the defense information technology community can gain a mutual understanding of defense needs and industry capabilities and identify opportunities to integrate information technology innovations into the U.S. military strategy."

To address this issue, the CTNSP program implemented a number of efforts. One initiative was to commission a study by Dr. Alan Berman to assess the current status of the Department of Defense (DoD) Laboratories' work in Information Technology (IT) and the status of their relationship with the IT industry. Mr. Don DeYoung, a Senior Research Fellow at the CTNSP, assisted in the conduct of Dr. Berman's review and in the writing of the report. Together they constituted what will hereafter be referred to in this report as the Study Team.[2]

According to their charter, the Study Team was tasked to:

> "Assess the current status of the Department of Defense Laboratories' work in Information Technology and the status of their relationship with the IT industry. Specific attention will be focused on the extent of the laboratories' collaborations with commercial IT companies. If the scale /and or quality of the collaborations prove to be inadequate, then the impediments will be identified along with specific recommendations on how to remove them."

The scope of this review was later expanded to include the Laboratories' relationship with both academia and other DoD laboratories.

2. APPROACH OF STUDY TEAM

The dictionary definition of "Interaction" is:

> "Reciprocal action or influence of things on each other."

Clearly there is a large ensemble of ways that a DoD IT Laboratory, can interact with, commercial organizations, academia, FCRCs and other DoD and government organizations that sponsor IT R&D. The modes of interaction considered by the Study Team included:

- Cooperative Research and Development Agreements (CRADA)
- Sponsor directed joint activities with industry or academia
- Service as Contracting Officer's Technical Represent (COTR) for IT R&D contracts with industry and academia

[2] In April 2004, this study was revised to incorporate observations made by Dr. John Lyons, a Distinguished Fellow at NDU's Center for Technology and National Security Policy.

- Contractual relationship (Industry or academic organization works for DoD IT laboratory under contract)
- DoD IT Laboratory serves as contract monitor or agent for the Office of Naval Research (ONR) or the Defense Advanced Research Projects Agency (DARPA) to oversee / manage R&D activity with industrial or academic performing organization.
- 10 U.S.C.2563 "Sales of Articles or Services" agreements with industrial funding of DoD IT laboratories by industrial sponsors
- Faculty Sabbaticals or summer employment
- Licensing and royalty agreements
- Joint authorship of papers submitted to refereed journals
- Direct support of graduate student research (Salary and facility support)
- NRC/NAS/NAE Post-Doc programs
- Specialized local area Partnerships (e.g. Center for Commercialization of Advance Technology (CCAT))
- Membership in State or University sponsored consortia (e.g. California Institute for Telecommunications and Information Technologies (CAL (IT) ^{2})
- Ad Hoc professional relationships between Laboratory staff members and their peers in industry and academia
- Community Interactions (Service by DoD IT Laboratory staff members on University, FCRC, Professional Society and Community advisory boards and Panels)

The Study Team found that the forgoing list is not exhaustive of the modes of 'Interaction' that exist. All of the organizations reviewed by the Study Team could claim that to one degree or another that they used all of these modes of interaction.

In response to its tasking, the Study Team visited the following DoD IT laboratories

- The SPAWAR Systems Center San Diego (SSC-SD)
- The Naval Research Laboratory (NRL), Washington DC
- The Air Force Research Laboratory Information Directorate (AFRL/IF) or (AFRL-RRS) Rome, NY
- The Communications-Electronics Command (CECOM) Research, Development and Engineering Center (RDEC), Fort Monmouth, NJ
- The Marine Corps Warfighting Laboratory (MCWL), Quantico VA

A typical visit involved an initial informal interview with the senior technical official and members of the senior management staff. The objectives of the visit were explained and the reactions of local management to the issues of laboratory interactions with Industry, academia, FCRCs and sponsoring organizations were elicited. The informal interview was typically followed by a formal brief that presented the organization's overview of the situation. The overview brief was followed by briefings presented by 8 to 12 mid-level managers (typically branch heads) who discussed their programs, constraints, branch culture, and interactions with external organizations. Time was left for interactive discussions between the Study Team and the presenters. At the end of the day, a wrap up discussion was held with senior laboratory management that was used to discuss the sub-group's impressions.

3. IMPORTANT REALITIES AND CONSIDERATIONS

Large organizations such as the DoD IT Laboratories are an assemblage of sub-groups and are therefore not monolithic in their approach to interactions with industry and academia. Each of these sub-groups lives in an inherently different environment, operates under different constraints, and has a somewhat different internal culture.

As an example, the Technical Director of a DoD IT Laboratory might honestly be proud of the organization's overall excellent NRC/NAS/NAE Post-Doc program, however, a detailed examination might reveal that the laboratory's NRC/NAS/NAE Post-Doc program is limited to only a small percentage of the sub-groups or branches within the laboratory. Often, in spite of strong urging by laboratory management, the pattern of differential interactions within a laboratory remains refractory to solution.

Many separate activities exist under the rubric of Information Technology. Often commercial firms in the IT field work in areas, which have applications and markets that, are exclusively civilian in nature. Such firms often exhibit a strong inclination not to interact with government agencies or with DoD IT laboratories. Other firms, such as QUALCOM have a virtual monopoly on a given area of Information Technology (Code Division Multiple Access (CDMA) in QUALCOM's case). In such circumstances, unless the firm is performing under a DoD contract, there is little, if any, incentive on the part of the firm to interact with a DoD IT laboratory. (The incentive might even be negative if the firm believes that such interactions might dilute their industrial advantage)

Some of the organizations reviewed by the Study Team devote a large part of their programmatic and personnel resources to activities that are classified above the GENSER SECRET level. In such program areas, interactions between DoD IT laboratories and Industry, FCRCs and Academia certainly take place. However, the Program Executive Officer (PEO) who controls the program maintains tight control on the scope and nature of these interactions and the DoD IT laboratories cannot increase or extend these interactions on their own volition.

4. DISCUSSION OF INDIVIDUAL ORGANIZATIONS

4.1 SPAWAR System Center- San Diego, California (SSC-SD)

On 21 January 2003 SSC-SD hosted a visit by members of the Study Team. The visit started with an overview of mechanisms and processes employed by the center to achieve interactions with industry, academia and other organizations. Thomas Kaye, the Deputy Executive Director for Science, Technology and Engineering, presented the overview. His presentation was followed by 10 individual presentations by middle level managers from various branches and divisions of the Center. An outline of some of the representative branch and division level presentations is provided in Appendix A. These provide an indication of the very broad range of approaches that are employed throughout the Center and an indication of the diversity of environments amongst various components of the Center.

In both, the Center overview, and in the individual presentations, the point was stressed that the Center uses many approaches to the problem of achieving effective interaction with external organizations involved in the world of IT. No single branch or sub-group used all of the possible modes of interaction listed above. The circumstances and constraints imposed upon each branch are different, and each branch tends to employ a different strategy to accomplish the external interactions it deems necessary and appropriate.

The Center's overview presentation highlighted both the successes and difficulties that it has encountered in achieving meaningful interactions with external organizations. These may be summarized as follows

- **Compartmented work.** Of SSC-SD's total workforce of 3450 people, about one third work in areas requiring special compartmented intelligence (SCI) clearances. The work, which encompasses more than a third of the dollar value of SSC-SD's total program, ranges from 6.2 to support to operations. The primary areas of effort include Intelligence Surveillance and Reconnaissance (ISR) systems, analytic aids, Information Operations (IO), Low observables, Human factors, and covert communications. For this effort, 40 percent is performed in house, 50 percent is performed by industry, 5 percent is performed by other government agencies and 5 percent is performed by Academia and FCRCs. Interactions with external organizations are controlled the sponsoring agencies. Although significant interactions with commercial IT firms take place, many of the normal modes of interaction are infeasible.

- **In-service engineering support.** A significant component of the Center's program and personnel is devoted to a group of activities that can be referred to as in-service engineering (i.e., Repair, adjustment, recalibration and modernization of in-service IT equipment). These activities are of utmost importance to the Center's sponsors and to the operational Navy. However these activities do not result in professional interactions with the IT industry except in the context of contracts with industrial organizations that are designed to support and extend the Center's capabilities to provide in-service engineering support.

- **System integration efforts.** By far, the most important and perhaps largest responsibility of the Center is to serve as a systems integrator for its parent command. The Center puts IT systems together and subjects them to extensive testing and modification. The IT systems that the Center integrates are composed of components developed by industry. Here the interaction with the IT industry is at its most fundamental. Commercial components are rarely suitable for introduction into Navy system without some degree of modification. Working level engineers from the IT industry and their peers at the Center must collaborate to understand the implications of proposed modifications on system cost and system performance. Interface protocols must be established that allow industrial products to work with one another. The interactions in these activities provide Center engineers and technicians with a detailed understanding of products and concepts being fielded by the IT industry.

- **Cooperative Research and Development Agreements (CRADAs)** The Center makes extensive use of CRADAs to interact with commercial IT organizations to accelerate the transfer of Center-developed technology and concepts to industry, so that when Industry bids on Navy systems, the Center's technology and concepts will have an improved probability of being incorporated in such bids. The achievement of these CRADAs requires a pro-active effort by the Center to introduce Industry and Academia to the Center's accomplishments and to 'sell' them to these organizations. Among the current CRADAs the Center listed:

  AAI Corporation: Adaptation of Data Link Test Tools
  Boeing Company: Maritime Surveillance Operations Center
  SUN Microsystems Federal, Inc.: Network–Centric Computing
  Raytheon: Autonomous Surveillance Sensor Array
  Photonics Components International: Wavelength Division Multiplexing
  Unconventional Concepts, Inc.: Disease Risk Assessment
  University of Southern Mississippi: Sound Analysis and Behavior Research

- **NRC/NAS/NAE Post-Doctoral Fellowship Programs.** The Center has participated in the NRC/NAS/NAE Post-Doctoral fellowship programs. Discussion with the Study Team indicated that in the past success in this area had been modest. The principal problem encountered by the Center during the Dot COM boom period of the 1990s was that freshly minted PhDs with an IT background were commanding starting salaries of $80,000 to $100,000. The Center's salary offers were limited to about $40,000 and were clearly non-competitive; thus it was difficult to attract Post-Docs in the IT field. With the burst of the Dot COM bubble, the situation has alleviated and the Center is now able to report some recent success in hiring in this field.

- **Patents and Royalty Licenses.** The Center has a program to license its patents to Industrial and Academic activities. A percentage of the royalties is given to the patent holder and the rest is retained by the Center. Because the total funds involved are relatively small (about $400K) compared to the Center's total cash flow, the Center does not seem to have an aggressive program for either stimulating the production of

patents or encouraging the marketing of licenses. The Center has current active royalties licenses and payment agreements with the following companies:

Applied Microsystems: Underwater Spectroscopic Detector
Honeywell International,
Microphase Corp.,
Photon Controls,
Uniphase: Fiber Optic Couplers
Metron: Computer Graphic Software to produce maps with polygon
Ocean Test Equipment Inc.: Bioluminescent Bioassay System
Optron Systems Inc.: Ultra-high Resolution Liquid Crystal Display

- **10 U.S.C § 2563 "Sales of Articles or Services" agreements.** Under Tile 10 U.S.C. § 2563 Industrial organizations can enter into consortia with DoD Laboratories and Centers to bid on Broad Area Announcements (BAAs) for projected contracts to develop or produce new systems. In such arrangements the Center, in effect, becomes a sub-contractor to the prime contractor. Although, many prime contractors have been enthusiastic about the benefits of such industry teaming arrangements, in practice, the execution of contracts to establish them has proven difficult. Legally, a prime contractor could not sue the Center if the Center failed to perform or under-performed on a contract. Attorneys for prime contractors have been cautious about allowing their companies into a legal situation where they might be held accountable for failure occurring as a result of possible performance deficiencies of a sub-contractor over whom they have no legal recourse.

  This problem has acted as an impediment to the establishment of such relationships, but has not proven to be a showstopper. The best "work around" for this class of problem has proven to be a Memorandum of Understanding (MOU) between the Center, the prime contractor and the project manager. Under such MOUs funding from industry goes to the Center via the project manager but tasking goes directly from industry. In effect the Center works for the prime contractor. Although the total funds scheduled to be transferred to the Center via this route in FY 03 are only about $6.2M, the mechanism shows promise for the improvement and expansion of Industry-Center relationships. The Tile 10 U.S.C. § 2563 relationship is being used in the following programs:

  Submarine LF/VLF receiver (SLVR)
  Link 16 antennas
  Uninhabited Combat Air Vehicles (UCAV)
  CVN-77
  DD-21 Topside definition
  Raytheon Support for DD (X)
  Coast Guard Great Lakes Icebreaker (GLIB) (Commercial Services agreement with Marinette Marine Corporation)

- **San Diego University/ Industry/ Government Partnerships.** SSC-SD, Orincon Technology, San Diego State University (SDSU) and the University of California San Diego (UCSD) jointly operate a Center for the Commercialization of Advanced Technology (CCAT). The mission of CCAT is to identify technologies that have commercial or dual use potential for the DoD. Recently, the focus of CCAT has been the areas of consequence management, missile defense and other government technologies. A number of examples show the effectiveness of CCAT in transitioning SSC-SD developed technology to industry. In DDR&E's most recent report to Congress CCAT was reported to be one of the gems of SSC-SD's activities. Additional CCATs are now being planned for other areas of California and for Hawaii.

- **California Institute for Telecommunications and Information Technologies (CAL (IT) 2).** (CAL (IT) 2) is an initiative of the State of California managed by two southern California Universities (UCSD and UCI) whose purpose is to ensure that the state maintains its lead in IT and telecommunications. SSC-SD along with the major local universities and more than 50 local IT and Telecommunication companies are involved in this consortium. Although the consortium sponsors meetings and colloquia that permit working level interactions between Scientists and Engineers at SSC-SD, the consortium is more than a marching and chowder society. Over the last 5 years approximately $500 Million has been made available through contributions of the State ($100 M), Federal R&D grants ($200 Million), and industrial and private contributions ($200 M). This fiscal muscle has permitted the consortium to foster meaningful interactions within the local area IT and Telecommunications community. SSC-SD is a card-carrying member of this community and profits from its interactions with other members of this consortium.

- **Ad Hoc Collegial relationships with University Faculty members and Graduate students.** Although difficult to describe precisely, the mechanism of ad hoc collegial relationships between university faculty members and graduate students is by far the most leveraged source of interactions between the Center and Academia. It results in collaborative research projects, faculty sabbaticals, and IPA tours at the Center. More importantly, Graduate Students who are supported by the Center and allowed to use Center facilities to do their thesis research have a high probability of becoming permanent Center employees when receive advanced degrees. ONR has provided significant support for this class of interaction with the Academic community. The Study Team takes note of the fact that a listing of the Universities involved in such interactions is not limited to the southern California area. Interactions take place both with Universities located throughout the United States and with a significant number of foreign Universities.

  The success of this class of interaction seems to be largely dependent on the reputation and enterprise of a relatively small group of distinguished scientists at the Center. These are people who have worldwide renown in their field of excellence and have a capability to influence ONR and DARPA funding for their academic colleagues.

The engineering and technology communities also have collegial contacts with their professional peers in industry. Unfortunately, for these communities formal contractual relationships are generally required for collaborative efforts.

Assessment of SSC-SD's external interactions.

SSC-SD does indeed have extensive interactions with Industry, Academic, and Government organizations. As indicated in the discussion above, and in Appendix A, these interactions have many forms.

Groups at the Center that are primarily involved with S&T programs, either as performing activities or as agents of S&T funding activities (e.g. DARPA and ONR), tend to have the greatest interactions with Academia. As a general rule, groups at the Center that work in restricted access areas , do in-service engineering, or serve in an integrating role for the Center's sponsors, tend to have more limited interactions with Academia than groups involved in S&T activities. This is neither surprising nor unreasonable. The interests of the Academic community tend to be focused more on basic research than on development, restricted access programs or in-service engineering. The Study Team developed the perception that the Center's interactions with Academia were flexible and continuously adapting to new circustances and opportunities.

Strong interactions exist between the Center and some components of the IT industry. Here the nature and the level of the interactions are controlled between the self interest of the Center and possible industrial IT partners. Where a symbiotic relationship is feasible, coorerative activities take place.

Where there is no economic or technical advantage, or when there is no commonality of technical fields of interest, neither industry nor the Center attempt to establish cooperative activities. The mechanisms, ranging from CRADAs to Title 10 U.S.C. § 2563 "Sales of Articles or Services" agreements, that are used by the Center are discussed above. Generally, these mechanisms prove to be effective means of establishing the desired relationships. Problems are on occasion encountered. However, with sufficient resourcefulness on both sides "work arounds" are generally developed.

The Study Team developed the perception that at all levels the management of SSC-SD understands the value and importance of meaningful interactions with the IT industry and with relevant components of Academia. Where problems have been encountered alternative approaches have been used.

4.2 Communications-Electronics Command -Research, Development and Engineering Center Fort Monmouth, New Jersey (CECOM-RDEC)

On 11 February 2003 CECOM-RDEC hosted a visit by members of the Study Team. The RDEC has four principle directorates.

- Space & Terrestrial Communications Directorate (S&TCD)
- Command & Control Directorate (C2D)
- Intelligence and Information Warfare Directorate (I2WD)
- Night Vision & Electronic Sensors Directorate (NVESD)

NVESD is located at Ft. Belvoir, Virginia and was not represented directly at the briefings presented to the Study Team. Several offices that report to RDEC headquarters augment the activities of the four major RDEC directorates. These are the Army Systems Engineering Office (ASEO), Information Systems Integration Office (ISIO), the Digital Integration Laboratory (DIL), the System of Systems Integration Office (SoSI), and the Technology Transfer Office (TTO).

Although TTO does not have exclusive responsibility for technology transfer, its specific mission is to foster technology transfer to and from industry, academia, other services and state agencies, and to promote the leveraging of technology. TTO programs and efforts include the oversight of:

- Cooperative R&D Agreements (CRADAs)
- Patent Licensing Agreements (PLAs)
- Small Business Innovative Research (SBIR)
- Dual Use Science & Technology (DUST)
- Independent Research and Development (IR&D)
- Collaborative Ventures-Information Technology Innovation Center (ITIC)

Any evaluation of RDEC's interactions with Industry and Academia must begin with RDEC's view of its position in the Army's Acquisition process. RDEC neither performs basic research nor initiates in-house development of technology. RDEC believes that its mission is to Adopt, Adapt, and {then to} Develop technology for insertion into Army systems that are currently in the development phase under the supervision of a Program Manager (PM) or a Program Executive Officer (PEO). In the Army acquisition system a Lead System Integrator (LSI) is usually selected. Since the LSI effectively makes decisions about the inclusion of specific technologies in a system development RDEC must persuade the LSI to include specific items of technology that have been brought to maturity under its sponsorship.

Given its view of its mission, RDEC personnel are convinced that institutional survival requires the existence of broad and effective interactions with industry, academia and other entities in the world of IT technology. In both, the RDEC management overview, and in the individual presentations by members of the RDEC staff, the point was stressed repeatedly that, the RDEC

uses many approaches to the problem of achieving effective interaction with external organizations involved in the world of IT. No single sub-group or office within RDEC used all of the possible modes of interaction discussed in section 2 above.

RDEC differs from SSC-SD in that, according to its management, RDEC performs virtually no in-service engineering and only an estimated 5% of its total effort supports Special Access Programs. Thus the types of interactions with industry and other groups that are associated with such activities are largely missing at RDEC.

Although RDEC clearly has an institutional culture that fosters industrial and academic interactions in an extremely proactive and aggressive manor, the Study Team noted that the following techniques were not mentioned in any of the RDEC presentations:

- Faculty Sabbaticals or summer employment
- Joint authorship of papers submitted to refereed journals
- Direct support of graduate student research (Salary and facility support)
- NRC/NAS/NAE Post-Doc programs

The Study Team did not take the absence of mention of such techniques as an indication that they were not employed by the center. Rather the Study Team believes that RDEC has stressed the use of other techniques to achieve meaningful interactions with external organizations. These may be summarized as follows

- **Small Business Innovative Research (SBIR).** RDEC appears to regard its SBIR activities as the poster child of its portfolio of industrial interactions. In a very real sense, RDEC seems to have institutionalized the SBIR program into a surrogate for what would normally be the in-house 6.2 and 6.3 development activities. In effect, concept development and early technology innovation is developed through the SBIR program. Appendix B.1 lists 34 companies that currently have SBIR contracts with RDEC.

  RDEC views its SBIR program as a critical element of its technology base effort. SBIR is considered to be a vehicle that enables concepts generated by small businesses to be matured/steered into the Army's communications technology base. Nationwide Broad Area Announcements (BAAs) are published annually. The topics announced in the BAAs are tailored to meet areas of risk within the Army's communications thrust area and are tied to RDEC's thrust areas, which in turn are aligned with Army transformation objectives.

  RDEC and its customers within the service (i.e. PEO, Battle labs, Training and Doctrine Command (TRADOC)) are involved jointly in topic selection. Prioritization of topic and contractor selection takes place at every stage of the proposal selection process. The status of these programs is monitored closely. Quarterly reports are provided to RDEC's internal leadership on all of the maturer (phase II) projects. Annual reports of progress are provided to external customers.

RDEC has found that this process has allowed it to establish programs within less than one year to meet emerging needs. (i.e. Home Land Security (HLS), Ultra Wide Band (UWB), and Satellite Communications (SATCOM)). Many examples were provided to the Study Team of successful results that have produced technology that the Army's LSIs have incorporated into current developments.

RDEC personnel spoke of their SBIR programs with considerable enthusiasm. They believe that the SBIR program creates competition among large business defense contractors to meet specific tech requirements and to drive costs down.
They also believe that the SBIR program mitigates high-risk areas of R&D in its technology base and that reduced risk technologies can thus be passed on to its PM customers. Finally, RDEC pointed out that its program in this area allowed it to broker marriages between SBIR companies and large DOD contractors.

- **Cooperative Research and Development Agreements (CRADAs).** Although RDEC appears to make less extensive use than SSC-SD of CRADAs to interact with commercial IT organizations; RDEC management views CRADAs as an important conduit for such interactions. CRADAs are a vehicle that allows RDEC to accelerate the transfer of in-house developed (or matured) technology and concepts into Army system development.

.

The Boeing Company is the Army's Lead System Integrator (LSI) for the Future Combat System (FCS). In September 2002, Boeing and RDEC entered into an overarching CRADA with the FCS LSI for collaborative C4ISR technology development, integration, transfer and demonstrations.

Boeing has funded tasks at RDEC for the development of:

- A C4ISR Test-bed Tools for Readiness Demonstrations
- A Logical Database for FCS Information Management
- The definition of a Warfighter-Machine interface
- C4ISR On-The-Move Test-beds
- A realistic communications simulation of FCS operations via a Communications Effects Server
- A 'Stretched Hummer' outfitted for FCS LSI C2 On-The-Move utility demonstration

There are obvious benefits to both members of this Government-Industry partnership. Boeing as LSI finds that the CRADA mechanism allows it to leverage the results of RDEC's substantial C4ISR-related S&T investments, and the unique skills and capabilities of RDEC's people, and facilities. From RDEC's point of view the CRADA provides an opportunity for RDEC to transition requirements, concepts, and technology into FCS. The CRADA provides both partners with a fast, flexible mechanism for technical collaboration and a tight business, legal, and technical foundation.

- **Participation with the Rosettex Technology and Ventures Group.** As part of an ongoing effort to expand its mechanisms for the achievement of better interactions with industry and academia, RDEC has recently initiated participation in the Rosettex technology and Ventures group. Rosettex technology is a joint venture of SRI International and the Sarnoff Corporation and a team of over 60 leading Information Technology, market analysis and systems engineering firms. Rosettex is closely aligned with the Venture Capital (VC) community. It provides opportunities for the Government to exploit newly emerging commercial technologies from companies that have previously been reluctant to undertake government programs. In addition, it provides an opportunity for Rosettex's partners to commercialize promising technological developments. RDEC has entered into a 5-year, not to exceed $24 million, relationship with Rosettex. RDEC tasked the Rosettex group to undertake a wideband, satellite on-the-move communications study to determine the state-of-the-practice of commercial and military hardware and software solutions. In response to a small ($40K) tasking order, SRI and the Gartner Group executed a four-month literature search, survey and follow-up phone call activity that resulted in a summary table and recommendation for possible performing activities for the next phase of RDEC's effort.

- **Applied Communications and Information Networking (ACIN) activity.**
  The mission of the ACIN activity of RDEC's S&TCD is to empower government users to capitalize in an effective and efficient way on technology emerging from the commercial and consumer communications and networking industries by leveraging advances and influencing development efforts. In support of its ACIN mission the S&TCD supports:

  Educational workshops and seminars
  A set of educational workshops and seminars have been developed which provide the insights and knowledge necessary for warfighters to be leaders in applying information technology to battlespace and peacekeeping application and to achieve information superiority. The material developed for these workshops and seminars stress the techniques that are employed by commercial activities allow rapid changes to be made to networking information infrastructures when urgent situations so require.

  An Applied Communications and Information Networking Laboratory
  The ACIN laboratory provides participants in workshops and seminars with "hands-on" experiences in the design, configuration and operation of complex networks and associated network-based application. In addition to providing "hands on" capabilities to workshop participants, this asset is available to companies in the ACIN "incubator" as needed.

- **The Camden Center for Entrepreneurship in Technology**
  The Camden Center is an incubator activity where Drexel University, the Sarnoff Corporation and RDEC act in concert to mentor newly formed companies and activities. There are currently 12 companies in the incubator. A number of additional start up activities have applied for admission.

The Camden Center has enabled the rapid commercialization of technologies that demonstrate both commercial and DoD utility by providing an innovative environment and business creation mentoring. It also draws on successful models for creating technology ventures. These new technology venture companies will use venture capital resources to satisfy commercial marketplace needs enabling DoD to leverage DoD's seed investment to achieve more rapid product and service availability.

From the stand point of DoD the Center has been remarkably productive. In the calendar year 2001 companies in the center produced:

- Two User Empowered Access Control systems successfully delivered and demonstrated to the Biometrics Management Office (BMO).
- A 5-watt power amplifier with a 30Mhz to 450 MHz bandwidth was delivered which meets specification for the JTRS radio
- An Intra-aural transducer and electronics package was designed and fabricated to evaluate the feasibility of wireless hands free communications for special operations personnel in high noise environments.
- A low cost Ka band satellite receiver terminal was designed and developed that employed low temperature ceramic materials.
- An Architecture study was delivered that evaluated the extent to which commercial/cellular PCS could be leveraged with Unmanned Aerial Vehicles (UAVs) to provide communications on demand to the warrior.
- A "Smart Antenna" was designed and fabricated for application in high Multipath and Interference environments in the PCS spectrum.
- An 802.11/Bluetooth/GPS testbed was implemented which allowed the evaluation of interference issues associated with these technologies.

- **University Alliances.** Directly or indirectly RDEC interacts on an *ad hoc* basis with a number of individual universities. It also is involved with several University Alliances which provides an opportunity for an interaction with a multiple - University / Industrial consortium. The Rutgers Center for Advance Information Processing (CAIP) is an example of such a consortium in which RDEC is involved.

CAIP provides a valuable mechanism for the establishment of government-industry-university interaction in forefront research in the field of Information Technology. CECOM is a member of CAIP's Industrial Advisory Board Participation in CAIP activities has allowed RDEC to leverage the DARPA-sponsored Distributed System for Collaborative Information Processing and Learning (DISCIPLE). This has in turn led to an evaluation of DISCIPLE for use as standard product in the Defense Collaboration Tool Suite (DCTS)

The CAIP effort in support of the Command and Control component of the Army's future combat system (FCS-C resulted in the development of technology applicable to the multi-modal interface problem—didn't understand this…it seems incomplete (integration of voice recognition, language interpretation, gaze tracker/spatial orientation, touch screen, and Tele-operation)

In the current fiscal year RDEC is exploring the development of a joint effort, within the DARPA Augmented Cognition program, that will be oriented to the development of techniques that will allow the Army to reduce its C2 staff requirements.

In FY 03 the CAIP partnership will provide RDEC with access to $5M of FCS-relevant technology research in the areas of Multi-media, human-machine communication, and Collaboration-based C2. In addition it will provide RDEC with access to and complementary laboratory facilities. RDEC's collaboration with CAIP has provided it with access to substantial amounts of relevant DARPA, NSF, NIST and State of New Jersey-sponsored research. It has also provided for beneficial coupling with 24 other industrial organizations (e.g. AT&T, CISCO, IBM, Intel, Kodak, ORACLE, Speechworks, SUN, Texas Instruments, Telcordia, Xybernaut, etc.)

Although The Johns Hopkins University/Applied Physics Laboratory (JHU/APL) is a Federally Funded Research & Development Center (FFRDC) that is primarily devoted to Navy programs, it does have contractual relationships with RDEC. A 4-year program has been established by RDEC at JHU/APL. APL has been tasked to provide Architectural Study Support and Information Exchange Requirements (IER) for FCS C2.RDEC's contractual relationship with JHU/APL has provided it with access to both APL's experience and expertise in Command and Control and to APL's extensive industrial contacts in the field of Information Technology.

- **Collaborative Technology Alliances (CTA).** RDEC's Command and Control Directorate (C2D) is represented on the research management boards of the Advanced Decision Architectures (ADA) CTA. The ADA CTA is sponsored by the Army Research Laboratory and is comprised of 5 industry and 7 university members. The industrial membership consists of the firms MicroAnalysis Design, Klein Associates, SA Technologies, ArtisTech, and SAIC. University membership includes Ohio State University (OSU), the Massachusetts Institute of Technology (MIT), Carnegie-Mellon University (CMU), New Mexico State University (NMSU), the University of West Florida (UWF), the University of Central Florida (UCF), and the University of Maryland (UMD).

  This CTA has been funded at $56M over a period of 8 years. The CTA's emphasis is on basic (6.1) & early applied (6.2) research and on the transition of new user-interface technologies and design principles that will permit a soldier to achieve a better understanding of the tactical situation, thorough evaluation of courses of action, and more timely decisions. RDEC's participation in the ADA CTA has allowed it to benefit from interaction with a broad range of academic and industrial IT research activities that are related to the Army's C2 needs.

- **Protocol Investigation for Next generation (PING**). A task force composed of the leading industrial organizations in the IT community is investigating network communications protocol technologies and communication architectures for the next generation of Internet Technology. Members of RDEC's Space and Terrestrial

Communications Directorate are active participants in the work of the PING task force.

Based on knowledge gained as a result of participation on the PING task force, S&TCD personnel are able to provide technical recommendations to the Army Systems Engineering Office (ASEO). These recommendations support decisions related to the development of the Joint Tactical Architecture (JTA), the Joint Tactical Architecture -Army (JTA-A), and other tactical architecture working groups. S&TCD personnel analyze the implications of the ongoing evolution of information technology on the Army's Enterprise Architectures. The objective is to ensure interoperability among legacy and planned protocols impacting Army Transformation and Future Combat Systems.

RDEC personnel assist materiel developers and Army Program Managers with technology transfer studies and the definition of requirements for mandated protocol standards. In addition they provide studies that help to determine the benefits of Army migration to new and emerging protocols. RDEC personnel also analyze the consequences of deployment, conduct experiments with interoperability mechanisms, and define required functional improvements in such network attributes as: Bandwidth, Quality of Service, IP mobility, Network Services, Net Management, etc.

RDEC provides a unique laboratory and analysis capability that is made available to members of the PING task force to allow an assessment of communications protocols that are emerging. In particular RDEC personnel determines the applicability /suitability of proposed Army architectures in the context of emerging Internet protocols. Protocols and architectures are emulated in a realistic Military Networking Environment. RDEC works with the PING task force to mitigate the risk associated with fielding new protocols. It maintains an open architecture approach, thus ensuring interoperability.

RDEC supports the IETF standard end-to-end networking model and thus helps to accelerate COTS and the insertion of emerging technology. In order to support its efforts with the PING task force, a number of cooperative agreements are in the process of completion. COMPAQ is negotiating with RDEC S&TCD so that S&TCD can serve as a beta tester for version 6 of the Internet Protocol (IPv6). Similarly, CISCO would like RDEC to serve as both an alpha and beta tester for its IPv6 Mini Router. Microsoft has requested that RDEC serve as a beta tester for its XP OS Telcordia has asked RDEC to beta test its Session Initiation Protocol

Assessment of RDEC's external interactions.

RDEC does indeed have extensive interactions with Industrial, Academic, and Governmental organizations. As indicated in the discussion above, and in Appendix B, these interactions have many forms.

Few if any groups at RDEC have S&T programs as a primary focus. Although RDEC does act both as an agent for DARPA and to some extent as a performing activity for DARPA, by and large, RDEC's main focus is in the area of technology adaptation. DoD laboratories and centers, which are not heavily involved in S&T activities, tend to have modest interactions with the scientific community of Academia. RDEC is no exception to this observation. There is of course a large component of Academia that is heavily involved in the development and application of technology. RDEC has substantial and meaningful interactions with this component of Academia. Through the use of the mechanisms discussed above (i.e., the Applied Communications and Information Networking (ACIN) activity, the Rutgers Center for Advance Information Processing (CAIP), Collaborative Technology Alliances (CTA), and the Camden Center for Entrepreneurship in Technology), RDEC maintains very strong and effective relationships.

The Study Team was impressed by RDEC's strong and aggressive interest in the Small Business Innovative Research (SBIR) program. RDEC appears to use this program as a surrogate for a strong in -house technology development program. Since RDEC's theme is to Adopt, Adapt and {then} Develop technology to support PMs, PEOs, and LSIs, the use of SBIR programs as a source of orphan technology makes a great deal of sense, as does RDEC's support and mentoring of start up companies in the Camden Center incubator.

Strong interactions exist between the Center and many components of the IT industry. Here the nature and the level of the interactions is amplified by brokerage role that RDEC plays between small businesses, PMs. PEOs, LSIs and large DoD contractors. RDEC also plays an important role as an intermediary between industrial standards setting activities and the Army.

RDEC uses mechanisms, ranging from CRADAs to Alliances to support cooperative activities with the IT industrial community. Generally, these mechanisms prove to be effective means of establishing the desired relationships. On occasion problems are encountered. However, with sufficient resourcefulness on both sides, work arounds generally can be developed.

The Study Team developed the perception that at all levels, RDEC management understands the value and importance of meaningful interactions with the IT industry and with relevant components of Academia. Where problems have been encountered alternative approaches have been used. The process of fostering interactions with the IT industry is working well at RDEC

4.3 The Marine Corps Warfighting Laboratory (MCWL) Quantico, Virginia

On 14 February 2003 MCWL hosted a visit by members of the Study Team. MCWL is the smallest and newest of the five organizations that were visited by the Study Team. MCWL has between 110 and 115 military personnel and about 70 civilians who are assigned to it. In addition to the effort centered at Quantico, Code 353 of the Office of Naval Research (ONR) and two of ONR's Future Naval Capabilities (FNC) programs operate in relatively direct support of MCWL. In addition, the Commanding General of MCWL is double -hatted as the Vice-Chief of Naval Research. Thus MCWL's effort must be evaluated in a somewhat broader context than the work carried out in Quantico.

MCWL's mission is to improve current and future naval expeditionary warfare capabilities across the spectrum of conflict for current and future operating forces by:

- Conducting concept -based experimentation and wargames to identify, develop and integrate operational concepts with tactics, techniques, procedures and technologies.
- Supporting the Marine Corps Warfighting Advocates (Command Element, Ground Combat Element, Aviation Combat Element and Combat Service Support Element); Marine Corps Combat Development Command; Training and Education Command; and Systems Command to meet Service specific requirements.
- Supporting Joint experimentation through Marine Forces Atlantic, the assigned lead for participation in U.S. Joint Forces Command's Joint concept development and experimentation program.
- Forwarding results of experimentation to the Marine Corps Expeditionary Force Development System (EFDS) with recommendations for action.

The Laboratory conducts experimentation using a concepts-based innovation and experimentation model. The model begins with an idea and proceeds through a capabilities refinement phase usually associated with wargaming, an experimentation phase, and a capability development phase within the EFDS.

Assessment of MCWL's external interactions.

Given its rather unique mode of operation, it is not surprising that MCWL has a limited portfolio of direct interactions with the IT industry and with components of academia that are devoted to IT. Direct interactions with the IT industry appear to be limited to industrial vendors who respond to MCWL's BAAs. MCWL's direct interactions with Academia appear to be limited to:

- The Applied Research Laboratory of Pennsylvania State University (ARL/PSU)
- Georgia Institution of Technology
- Carnegie- Mellon University (CMU)
- California State Polytechnic Institution (CALPOLY)

Unlike the other organizations visited in the course of this study, MCWL has little if any direct control over funding for external S&T efforts. As a result it has relatively modest interactions

with industrial and academic organizations that work in the area of innovative approaches to Information Technology. MCWL obviously has extensive contacts with industrial organizations that are trying to sell developed and operational civil IT systems to the military. Such organizations argue that there is no need for the Marine Corps, or for MCWL, to support a development process when the functional equivalent is more or less available as an off- the-shelf item. Industrial organizations of this type postulate the Marines need only to try the product or concept being sold, on an experimental basis, to demonstrate its tactical utility.

This approach was followed in the Extended Littoral Battle-space Advanced Concept Demonstration (ELB ACTD), which resulted in a major effort that was unable to transition into a fielded system. A similar pattern appears to be developing as MCWL, upon the urgings of industrial contractors, is preparing to experiment with the use of the Iridium satellite communication system as an alternate to the failed ELB concept. Although the Iridium system clearly works as advertised, it has the disadvantage that it provides limited communications in areas with heavy tree canopies. Further it offers limited capabilities for data transmission. The use of the Iridium system would not be the system of choice that might be suggested by industrial or academic groups that work in the area of innovative Information Technology.

The forgoing comments may tend to understate the true scope of MCWL's interactions with the IT community. MCWL is supported by, and interacts with ONR, DARPA, NRL and the Jet Propulsion Laboratory. These organizations have strong and extensive interactions within and throughout all components of the IT community. In effect they serve a brokerage function. MCWL's and the (Marine Corps') needs are disseminated to industry and academia by these organizations. Since ONR, DARPA, and to some extent NRL, act as funding agencies, little difficulty is encountered in fostering interactions with innovative IT organizations.

With the possible exception of the existence of a single IPA appointment (the Technical Director of MCWL is an IPA), none of the modes of interaction listed in section 2., appear to be employed.

Although members of the Study Team understand MCWL's mode of operation and the reasons for the limitations in its direct contacts with industrial and academic IT organizations, the members believe that there is room for improvement. Within ONR, DARPA, and NRL codes that have direct responsibilities for support of Marine Corps activities, efforts are made to foster interactions with MCWL and external IT organizations. Other components of these organizations that have substantial interests and responsibilities in the IT domain, pay little if any attention to the IT requirements of the Marine Corps or to the current interests of MCWL.

Any modern military service has significant IT needs and must keep aware of the rapidly changing technology in the field. The Marine Corps is no exception. Its concepts of Ship to Objective Maneuver (STOM) are intensely dependent on the solution to a number of perplexing IT problems. To date satisfactory solutions of these issues have not been fielded. The Study Team believes that the Marine Corps' needs could profitably be exposed to a wider industrial and academic community than it has been to date.

4.4 Air Force Research Laboratory-Rome Research Site (AFRL-RRS) Rome, New York

On 6 March 2003 AFRL-RRS hosted a visit by members of the Study Team. AFRL-RRS constitutes the Information Directorate of AFRL system. RRS has four technical divisions located at both the Rome, NY site and in Dayton, OH.

- Information and Intelligent Exploitation Division (IFE)
- Information Grid Division (IFG)
- Information Systems Division (IFS)
- Information Technology Division (IFT)

An evaluation of RRS interactions with Industry and Academia must begin with RRS's budgetary sponsorship. Of a total estimated FY 03 cash flow of about $600 million, $117 million is S&T funds provided by RRS's parent command AFRL. RRS management points out that approximately 80% of this amount is contracted out to industry and academia. Thus only about $23 million of the S&T funds available to RRS are used to support in-house S&T effort. Another $265 million of the funds administered by RRS is provided by DARPA. RRS acts as DARPA's agent and contracts these funds to industrial and academic organizations. Since RRS is responsible for monitoring the performance of the organizations receiving such funds, RRS has extensive professional contact with them. The remaining $220 million funds that will be available to RRS in FY 03 are provided by approximately 61 offices and agencies within the DoD and other parts of the government. Although RRS management did not provide a break down of the disposition of these funds, the impression was conveyed that a large portion of these funds was also contracted out to academia and industry.

In practice, RRS awards approximately 300 new contracts per year. At the present time, RRS is administering or monitoring 1800 active contracts that represent a cumulative expenditure of $3.1 Billion. Thus it is not surprising that 75 commercial organizations maintain offices close to the RRS campus. Clearly, RRS must maintain a high level of interactions with such organizations. RRS management estimated that it has a portfolio of programs with more than 200 large and small businesses and over 80 Universities.

RRS’s mode of operation seems to differ significantly from that of SSC-SD, CECOM-RDEC and NRL. Both SSC-SD and CECOM-RDEC appear to act largely in support of (and are largely supported by) the SYSCOMs of their parent service. RRS has limited direct tasking from AF SYSCOMs. RRS appears to have organizational attributes that are a cross between an organization like ONR and a SYSCOM that is not involved in the acquisition process (this may require additional explanation. What is meant by a SYSCOM not involved in the acquisition process?). This institutional focus is to some extent reflected in the make up of the personnel who carry out RRS’s mission. The organization ‘employs’ 768 scientists and engineers. Slightly less than 50% are civil servants. About 46% are industrial (or academic) personnel who work collaboratively on-site with RRS’s civil servants. The remaining personnel (4.5%) are military scientists and engineers. Under the circumstances, the organization must have inherently strong industrial and academic ties to execute its responsibilities.

RRS's management philosophy differs somewhat from that of CECOM-RDEC. As indicated above RDEC's view of its mission is to Adopt, Adapt and Develop technology. RRS believes that its mission is to Adopt, Adapt, and Influence the development of technology. The difference is significant and stems from the RRS's rejection of the classic linear model involving transitions from S&T to System Command (SYSCOM) development to SYSCOM procurement to service deployment. Examples of a number of RRS projects based on the concept of Adopt, Adapt and Influence are discussed in Appendix C.1

RRS believes that its job is to oversee the development of S&T and transition technology directly to industry with the hope that it can influence industrial organizations to use in their response to SYSCOM supported development activities. In order to make such a process work in an effective way, RRS must have interactions with industry that allow it to have a demonstrably significant influence on the technology that industrial organizations incorporate into approaches put forward in their responses to SYSCOM requests for proposals (RFPs). Examples of RRS's activities that serve to influence the transition of technology are provided in Appendix C.2

Given its view of its mission, RRS management, like that of CECOM-RDEC, is convinced that institutional survival requires the existence of broad and effective interactions with industry, academia and other entities in the world of IT technology. In the RRS management overview and in the individual presentations by members of the staff, the point was stressed repeatedly that the RRS uses many approaches to the problem of achieving effective interaction with external organizations involved in the world of IT.

RRS achieves its desired industrial and academic interactions through:

- Contracts it administers for DARPA and other agencies
- Participation in academic, industrial institutes that are also supported by New York State
- A SBIR program
- Cooperative Research and Development Agreements (CRADA)
- Sponsorship of seminars and symposia that are designed to interest industry and academia in IT problems of interest and consequence to the U.S. Air Force, and the DoD generally.
- Publications in refereed journals
- Availability of on-site collaborating S&E contractor personnel

RRS management presented examples of these approaches. Each example included extensive lists of participating industrial and academic organizations. These examples are discussed in Appendix C

Although RRS does not appear to have as aggressive a Small Business Innovative Research Program (SBIR) as was observed at RDEC, RRS's SBIR program is robust. The goal of RRS's SBIR program is to develop and prepare technology for insertion into Air Force weapon systems and for commercial spin-offs. RRS's SBIR program is designed to stimulate technology innovation by small businesses. Typically, AFRL-RRS is allocated 25-35 topics per year that can be addressed by SBIR programs. This allows for proposals of 80-90 small businesses per year. RRS's SBIR program has an annual budget of $20-25M per year and represents the largest single discretionary component of RRS's funds.

RRS has a number of active CRADAs with industrial organizations. These organizations include

Lockheed Martin: C-135 fiber optic network backbone
Raytheon: C-130 antennae
BOEING: JBI
NYSTEC: NY State network
ITT: Threat emitters
Interscience: MEMS
Booze Allen and Hamilton: ISR software

RRS is also involved with a number of dual use S&T projects. These projects involve both academic, industrial and governmental organizations:

MTL Systems Inc: digital watermarking
Kodak: steganography
ORINCON: information assurance
ARCA Systems: information assurance

Although it performs virtually no in-service engineering, RRS differs from SSC-SD and CECOM-RDEC in that it appears to support significant levels of effort in Special Access and Compartmentalized Intelligence Programs. Thus the types of interactions with industry and other groups that are a concomitant of in-service engineering activities are largely missing at RRS. However, those that are a concomitant of participation in Special Access and Compartmentalized Intelligence Programs are undoubtedly present.

Although RRS clearly has an institutional culture that fosters industrial and academic interactions in an extremely proactive and aggressive manor, RRS management is very proud of their extensive use of the following as means of interacting with the academic community, sources of recruitment of new personnel, and as a source of intellectual renewal of the RRS staff.

- Faculty Sabbaticals or summer employment
- Joint authorship of papers submitted to refereed journals
- Membership in University/Industrial/ Governmental Consortia and Institutes
- Direct support of graduate student research (Salary and facility support)
- NRC/NAS/NAE Post-Doc programs

Examples of RRS's participation with University/Industrial/ Governmental Consortia and Institutes are provided in Appendix C.3

Assessment of AFRL-RRS's external interactions

The fundamental observation to be made about AFRL-RRS is that it has truly extensive contacts with the Industrial Information Technology community. As shown in Appendix C.5, RRS has performance contracts with dollar values between $20 million and $75 million with industrial corporations. It has similar contracts in the range between $10 million and $20 million with 7 industrial corporations. A total of 23 firms hold contracts with AFRL-RRS that have dollar values between $5 and $10 million and another 17 firms have contracts valued between $1 million and $5 million. Finally, a total of 49 firms hold performance contracts with AFRL-RRS that have dollar values of less than $1 million. Upon review of Appendix C.5, it was hard for members of the Study Team to think of any first rate Information Technology firm that was not under contract with AFRL-RRS

4.5 The Naval Research Laboratory (NRL)

On 12 March 2003 NRL hosted a visit by members of the Study Team. Although, NRL's overall budget (or cash flow) is larger than that of CECOM-RDEC and AFRL-RRS, the amount that is allocated for work in the area of Information Technology is less than 10% of NRL's overall budget. In that sense, NRL's total efforts in Information Technology, if measured only by the budget of NRL's Information Technology Division (ITD), is significantly less than that of RDEC and RRS.

A somewhat unbalanced view is probably obtained, if NRL's total Information Technology effort is assessed only by the effort of its IT Division. In addition to the work of the ITD, much of the work of NRL's Electronic Warfare Division, its Optical Sciences Division and its Centers for Space Technology and for Tactical Technology Development can be classified, quite properly, as involving Information Technology. For reasons of time and in most cases for reasons of classification, the Study Team reviewed the IT activities of only the ITD and a small piece of the NRL Naval Center for Space Technology (NCST), which was the Tactical Special Projects Office (TSPO).

NRL's ITD, one of 18 Divisions at NRL, conducts research and development programs in the collection, transmission, and processing of information to provide a basis for improving the conduct of military operations. The organization of the Division is directed toward addressing the technologies and subsystems necessary to develop architectures and system designs for the next generation of Battle Force warfare systems. A discussion of the ITD's programs and management philosophy is provided in Appendix D.

In FY 2001 the ITD's total program amounted to about $70.5 million. Of this amount, about 41% were in S&T funds (6.1/6.2/6.3) and the remaining 59% of its funds were from a large number of other sponsors including DARPA. Although, on occasion, NRL acts as an agent for DARPA, unlike RRS, it regards itself as a performing laboratory and it does not regard the administration of DARPA contracts as a prime activity. Under the circumstances, NRL ITD does not have the broad industrial relations that are characteristic of a primary contract agency or its immediate agents. Within the Navy, the ONR contract research program has primary responsibility for the support and sponsorship of S&T. Thus the level of industrial and academic interactions that exist at RRS are resident at ONR, not at NRL.

The Adopt, Adapt, Influence or Adopt, Adapt, Develop approaches of RDEC or RRS do not drive NRL. NRL's ITD views itself as a performing activity that generates (or lays the basis for the development of) technology that may be transferred to, or further developed by, industry. In concept, such NRL inspired, or developed, technology will then be used by industry, when industry responds to the Navy's acquisition programs. NRL's Centers for Space Technology and for Tactical Technology Development view themselves, as being organizations whose mission is to take technologies that have been proven successful in some highly classified applications (that are not generally available to industrial organizations) and incorporate them into specialized applications. NRL's secure mobile communications network for a presidential limousine is an example of such limited but important applications.

Thus the nature and extent of NRL's interactions with both Industry and Academia are predictably different than those of RRS and RDEC. ITD management can indeed provide lists of CRADAs, SBIR contracts, MOAs and MOUs. However, the ITD's most significant interactions with industry and academia tend to be limited to specific collegial interactions among peers who can provide intellectual support for each other. On the other hand, the interactions of the NCST and the TSPO with industry and academia tend to be weighted towards industrial organizations that have supported and developed past technology for NRL's extensive classified programs. Such organizations have the clearance accesses that allow the NCST and the TSPO to use them as subcontractors that can participate in the many customized system development and acquisition projects that NRL manages.

NRL's patterns of interactions with Industry and Academia have many of the attributes associated with SSC-SD that were discussed above in Section 3.1. For NRL, the Study Team notes the following attributes:

- **Compartmented work.** Of NRL's total workforce involved in Information Technology related activities, a significant fraction of the ITD, the NCST, the TSPO, the Optical Sciences Division and the Electronic Warfare Division, work in areas requiring special compartmented intelligence (SCI) clearances. The work, which encompasses a large fraction of NRL's total program, ranges from 6.2 to support to operations. In these program areas, interactions with academic and industrial organizations are controlled by the sponsoring agencies. Although significant interactions with commercial IT firms take place, many of the normal modes of interaction are infeasible.

- **In-service engineering support.** A component of the NRL IT program and personnel is devoted to a group of activities referred to as in -service engineering (i.e., repair, adjustment, recalibration and modernization of in -service IT equipment). These activities are of utmost importance to the NRL's sponsors and to the operational Navy. However these activities do not result in professional interactions with the IT industry except in the context of contracts with industrial organizations that are designed to support and extend the NRL's capabilities to provide in -service engineering support.

- **System integration efforts.** A relatively small component of NRL's program support causes it is to serve as a systems integrator for some of its sponsors. In some instances, NRL's IT community puts systems together and subjects them to extensive testing and modification. The special purpose IT systems that the NRL integrates are composed of components developed by industry. Here the interaction with the IT industry is at its most fundamental. Commercial components are rarely suitable for introduction into the special purpose customized systems that NRL develops without some degree of modification. Working level engineers from the IT industry and their peers at the Laboratory must collaborate to understand the implications of proposed modifications on system cost and system performance. Interface protocols must be established that allow industrial products to work with one another. The interactions

in these activities provided NRL engineers and technicians with a detailed understanding of products and concepts being fielded by the IT industry.

- **Cooperative Research and Development Agreements (CRADAs)** NRL's IT community makes limited but effective use of CRADAs to interact with commercial IT organizations. The motivation here as is the case with SSC-SD, is to accelerate the transfer of NRL- developed technology and concepts to industry, so that when Industry bids on Navy systems, NRL's technology and concepts will have an improved probability of being incorporated in such bids. The achievement of these CRADAs requires a pro-active effort by the NRL to introduce Industry and Academia to the NRL's accomplishments and to 'sell' them to these organizations. A listing of current CRADAs is provided in Appendix.

- **NRC/ NAS/NAE Post-Doctoral Fellowship Programs.** Over the last fifty years, NRL as a whole has participated vigorously and aggressively in the NRC/NAS/NAE Post-Doctoral fellowship programs. Unfortunately, the participation of NRL's IT community in this program has been less than the rate of participation of the laboratory as a whole. The problems encountered were similar to those encountered by SSC-SD. During the Dot COM boom period of the 1990s, freshly minted PhDs with an IT background were commanding starting salaries of $80,000 to $100,000. NRL's salary offers were limited to about $40,000 and were clearly non-competitive. Thus it was difficult to attract Post-Docs into NRL's IT community. With the bursting of the Dot COM bubble, the situation has alleviated and NRL's IT community is now able to report some recent success in hiring in this field.

- **University/ Industry/ Government Partnerships.** As discussed in Appendix D, NRL's IT community is involved in a number of such partnerships. However the significance and importance of such partnerships is less than was perceived at SSC-SD, RDEC or RRS.

- **Ad Hoc Collegial relationships with University Faculty members and Graduate students.** Although difficult to describe precisely, the mechanism of ad hoc collegial relationships between university faculty members and graduate students is by far the most leveraged source of interactions of the NRL and Academia. Examples are discussed in Appendix D. These interactions result in collaborative research projects, faculty sabbaticals, and IPA tours at the NRL. More importantly, graduate students who are supported by the Laboratory and allowed to use Laboratory facilities to do their thesis research have a high probability of becoming permanent Laboratory employees when receive advanced degrees. ONR has provided significant support for this class of interaction with the academic community. As is the case in SSC-SD, the success of this class of interaction seems to be largely dependent on the reputation and enterprise of a group of distinguished scientists at NRL who have worldwide renown in their field of excellence and have a capability to influence ONR and DARPA funding for their academic colleagues.

Professional interactions of NRL's Information Technology Division

As might be expected from an organization that has significant in-house S&T programs, the ITD, can point to many impressive, professional accomplishments.

In CY2002, in the area of publications, the ITD total amounted to 99 citable external publications. Of these 36 were published in refereed journals, and the remaining 58 were published other citable publications. In addition, ITD personnel authored 5 books or chapters in books.

As an indicator of the professional stature and reputation of division personnel, 11 members of the ITD served as full time members of editorial boards of professional journals. Two division members also served on the editorial boards of special issues of professional journals. The journals included:

- *ACM Distributed Computing*,
- *ACM Transactions on Software Engineering and Methodology*,
- *Automated Software Engineering* (Special Issue on Automated Verification of Infinite-State Systems),
- *Journal of Real Time Computing*,
- *Formal Methods and System Design* (Special Issue on Tabular Notation),
- *Requirements Engineering Journal*,
- *Journal of Software and Systems Modeling*
- *ACM Transactions on Information System Security*,
- *Journal of Computer Security*,
- *International Journal on Information Security*
- *IEEE Computer Graphics and Applications*,
- *Journal of Virtual Reality*,
- *Journal of Computer Graphics and Geometry*

In 2002, in the area of professional society Conferences and Working Groups, members of the ITD staff served on the Steering Committees or Board of Directors of six such Conferences and Working Groups. These included:

- IFIP WG 2.9 (Requirements Engineering),
- International Conference on Requirements Engineering,
- IEEE Security Foundations Workshop, New Security Paradigms,
- ICISA (International Communications and Information Security Association),
- IFCA (International Financial of Cryptography Association)

Division personnel also served as the General Chair of 4 workshops including:

- IFIP WG 1.7 (Foundations of Security Analysis and Design),
- RHAS (Requirements of High Assurance Systems),
- WITS (Workshop on Issues in the Theory of Security),

- 2nd International Workshop in Automatic Verification of Infinite-State Machines

NRL's ITD personnel also served as Program Chair or Session Chair of the following conferences:

- PETS (Privacy Enhancing Technologies),
- Visualization 01
- 23rd International Conference on Distributed Computing Systems (Software Engineering and Formal Methods),
- Mathematical Foundations of Programming Semantics (Computer Security)

NRL's ITD hosted the following visitors from Academia in 2002:

- 19 student Interns
- 2 ASEE participants (Morgan State and Paine State)
- 2 Post Docs
- 2 Visiting Scientists (Politecnio di Milano and University of Florida)
- 12 visiting Faculty & Midshipmen from USNA

NRL's ITD personnel also have hold part time adjunct teaching positions at the following 8 Universities:

- Old Dominion University (1)
- George Mason University (2)
- George Washington University (2)
- James Madison University (1)
- Naval Post Graduate School (1)
- UMBC (1)

Finally ITD personnel have recently served on Thesis Committees at the following Universities:

- Carnegie Mellon
- University of Cape Town
- Oxford University
- Saarland University, Saarbrücken

Assessment of NRL's external interactions.

NRL does indeed have extensive interactions with Industry, Academic, and Government organizations. As indicated in the discussion above, and in Appendix D, these interactions have many forms.

Groups at NRL that are primarily involved with S&T programs tend to have the greatest interactions with academia. As a general rule, groups at NRL that work in restricted access areas, do in -service engineering, or serve in an integrating role for NRL's sponsors, tend to have more limited interactions with academia than groups involved in S&T activities. As was the case with SSC-SD, this is neither surprising nor unreasonable. The interests of members of the academic

community tend to be focused more on basic research than on development, restricted access programs or inservice engineering. The Study Team developed the perception that NRL's interactions with academia were flexible and continuously adapting to new circustances and opportunities.

Strong interactions exist between NRL and some components of the IT industry. Here the nature and the level of the interactions are controlled between the self interest of NRL and possible industrial IT partners. Where a symbiotic relationship is feasible, cooperative activities take place. Where there is no economic or technical advantage, or when there is no commonality of technical fields of interest, neither industry nor the NRL attempt to establish cooperative activities. Many mechanisms, ranging from CRADAs to MOUs are used by NRL and its industrial partners to establish effective working relationships. On occasion problems are encountered. However, with sufficient resourcefulness on both sides work arounds are generally developed.

The Study Team developed the perception that at all levels the management of NRL understands the value and importance of meaningful interactions with the IT industry and with relevant components of Academia.

5. SUMMARY OF FINDINGS

This study was established "to find practical ways in which the defense information technology community can gain a mutual understanding of defense needs and industry capabilities and to identify opportunities to integrate information technology innovations into the U.S. military strategy." In addition, the study was to investigate the validity of the perception developed in an earlier study that some of the DoD laboratories with primary responsibilities in the area of Information Technology (IT) appeared to have relatively limited interactions with industry and academia, other than with their contractors. Some criticism was also made in the report that the laboratories also needed to improve their connectivity with each other and with the larger S&T community.

As indicated in Section 3 and in Appendices A through D, the work of the DoD Laboratories in the area of Information Technology, is on a worldwide basis at the forefront of professional activity. Although significant variability exists amongst the DoD Laboratories in their level and types of interactions with the IT industry and IT developments in academia, the interactions are generally strong and healthy.

Based on the findings of the Study Team, the scale and quality of collaborations between the DoD IT laboratories and the IT industry appear to be adequate. Many mechanisms are available to implement such interactions. Although some technical and legal impediments to interactions between DoD laboratories and industry were identified (see section 3.1 above), Industrial and Laboratory management have always been able to find "work-arounds." Such impediments as were discovered, (e.g. 10 U.S.C § 2563 "Sales of Articles or Services" agreements which permits industry to hire a DoD Laboratory as a sub-contractor, but does not permit industry to sue for redress in the event of inadequate performance by a DoD laboratory) do not warrant remedial action. Expedients are available that obviate the problem, such as reversing the roles of the two parties. The Laboratory can become the prime and the industrial member of the consortium can become the sub-contractor. Alternatively, fees can be (and have been) built into contracts to cover the possible costs to an industrial contractor if and when a DoD Laboratory sub-contractor does not perform as required in the contract.

The Study Team was impressed by the variety of techniques and methods employed by the different laboratories it visited. The means of choice for interacting with the IT industry is very much a function of the nature of work of each Laboratory, its perception of its mission and its sources of funding. Ultimately the Laboratories use the same techniques to foster interactions with Industry and Academia. Each Laboratory makes differential use of the totality of options that are available to it.

The staff of Marine Corps Warfighting Laboratory (MCWL) is constrained to engage in a limited set of activities in support of Marine Corps needs. Predictably, members of MCWL's staff have more limited professional interactions with the external IT community than do staff members at the other DoD IT laboratories. The management of the other four laboratories that the Study Team visited is justifiably proud of the professional interactions and the positions of influence that members of their staff hold in the worldwide IT community. Such personnel serve on industry standards committees, on professional society working groups, on editorial boards of

professional society journals, etc. To the extent that the Laboratories serve as S&T funding agencies, as research sponsors or as agents of research sponsors, it is hard to imagine any industrial or academic IT organization of any significance that does not interact with the DoD IT Laboratories.

The Study Team would like to underscore the importance to the military of having internal expertise to link to its external collaborators. Study after study have argued for having this internal capability so as to be able to advise senior leadership on acquisition decisions – the "smart buyer" role. We believe this means more than program managers but rather staff working in the internal laboratories on the same class of problems. In recent years we have also learned that the transition of new technology from one entity to another goes best when staff from both sides have worked on the problem in the laboratory in a collaborative manner. Indeed in some cases the staff actually moves with the technology. Within the scope of this study, the best examples of how to do this are at the NRL, as discussed in the previous section. We conclude that the other service laboratories keep this model in mind as they go about creating external links to needed expertise.

6. RECOMMENDATIONS

1. DoD should submit an annual report to Congress that summarizes the extensive nature of the entire range of interactions of DoD IT Laboratories with Industry and Academia. This report should be given broad dissemination and should be highlighted, as one of the significant contributions of these organizations, to the continuing development of the Nation's Information Technology infrastructure.

2. The Ad Hoc nature of the multiplicity of interactions that were discussed in this report should be institutionalized by a system of rewards and incentives. Among the rewards and incentives that should be considered are:

   - Financial awards and or other recognition for DoD employees who serve as co-authors of publications with colleagues affiliated with industrial or academic organizations.

   - The establishment of a designated overhead account that may be used to charge activities of DoD IT Laboratory personnel in support of national professional IT societies and standards setting panels.

   - Annual performance evaluation factors of senior DoD IT Laboratory managers should include activities that have resulted in demonstrable improvements in the interactions between their organizations and IT organizations in Industry and Academia

3. Agencies (DARPA, ONR. AFOSR, ARO) that sponsor IT S&T activities in DOD Laboratories, should be directed to designate a small fixed percentage of the funds that they transfer to the DoD IT Laboratories for exclusive use as seed money for the development and support of new interactions with Industrial and Academic IT organizations

4. When setting up external centers of excellence for collaboration, the military laboratories should:

   - Select the topical areas through a careful assessment of internal strengths and weaknesses.
   - Build external capability through consortia of academe and industry rather than individual firms or schools.
   - Make certain the internal matching strengths are well supported.
   - Manage the internal and external efforts as a single program. (Use new procurement authorities.)
   - Require agreement as to the movement of staff back-and-forth.

Appendix A

SSC-SD Branch and Division Level Presentations

A.1 Cryo-Tronics

S&T Project Description

Cryo-tronics is a monolithic (i.e. single-chip) hybridization of cryogenic semiconductor microelectronics with high temperature superconductor technology whose combination exploits the unique advantages of each technology, and in-turn leads to performance and capabilities unattainable by either alone. While super-conducting devices can make the best magnetic sensors and have much higher theoretical limits for speed than semi -conducting devices, there are certain functions, which they cannot perform well, such as interfacing with high signal levels of conventional electronics and memory applications. Semi -conducting devices can easily be used to support those functions, but cannot operate at such high speeds or perform magnetic detection with the same capability of the super conducting devices. Integrating the two technologies on a single chip provides a unique capability to exploit their respective strengths. Co-invented by SSC-SD and Conductus Corporation under a successful CRADA, commercial production is planned under a future CRADA with STAR Cryoelectronics.

S&T Project Relevance

Current magnetometers used for mine hunting and for anti-submarine warfare, use low temperature superconductor technology (that operates at 4 Kelvin, close to absolute zero!). This is extremely difficult to cool outside of a submarine's pressure hull, and also have less sensitivity, and self-induced noise. A multi-axis magnetometer and signal processing circuits fabricated using Cryo-tronics technology would improve sensing, reduce the complexity of the system (i.e., improve reliability) and reduce the system size. The ability to put low noise amplifiers co-located with the magnetic sensor is a major advantage for creating a portable magnetic sensor as it reduces the impact of environmental interferences. The technology can also be used for long-wavelength bolometric imagers with applications to missile defense in target discrimination and kill assessment. Applications in communications include super conducting filters and programmable delay lines. This technology allows communication systems to operate in closely-spaced frequency bands since super conducting filters have negligible losses and excellent rejection, and therefore can be exploited to improve performance. The negligible losses also provide for delay lines and electrically small antennas.

Industry, Academic, and DoD Laboratory Interactions:

SSC-SD and Conductus Corporation invented and demonstrated the core technology under Office of Naval Research funding under a successful CRADA. SSC-SD and STAR Cryoelectronics are currently negotiating a new CRADA to commercialize the monolithic magnetic sensor technology under the auspices of the Center for Commercialization of Advanced Technology (CCAT), a consortium of industry (Orincon Corporation), academia (University of California, San Diego and San Diego State University), and Government (SSC-SD). The purpose is to transition the technology into a manufacturing environment for the production of magnetic sensors using Super conducting Quantum Interference Devices (SQUIDs) integrated with cryogenic SOS devices, which can be used in both military and

commercial systems. In addition, to the transition of SSC-SD technology to STAR Cryoelectronics under a future patent license discussions have also started for an additional CRADA with SAIC, Inc. for their non-destructive testing products using this technology.

A.2 Wavelength Division Multiplexing Technology

S&T Project Description

Wavelength division multiplexing (WDM) technology enables multiple optical signals, each at a specific wavelength, to be transmitted and routed simultaneously over a common single fiber backbone. In this way, the information handling capacity and the functionality of a legacy fiber optic network or a planned network can be increased without major redesign or investment in the fiber backbone infrastructure. A key component of any WDM system is the device that performs the passive (no conversion of the optical signal to an electrical one and then back to optical) multiplexing and de-multiplexing of the optical signals. SSC-SD has researched and developed a specific class of a WDM mux/de-mux device referred to as a fused fiber WDM coupler. Work conducted at SSC-SD in 6.1-6.3 programs has included basic R&D on the physics of the optical coupling process, demonstrations of WDM fiber mixed signal distribution networks, and unique applications in optical signal processing and fiber optic gyroscope systems.

S&T Project Relevance

WDM is an enabling technology. It is used in a range of applications, from conventional data links to advanced navigational systems. A WDM fiber optic LAN or dedicated link allows for higher bandwidth data communications and simultaneous analog sensor data distribution throughout a military platform. Advanced fiber optic gyroscopes being developed by Honeywell International for next generation guidance and control systems for missiles, aircraft and submarines employ an SSC-SD fused fiber WDM coupler as a wavelength reference component for the gyroscope optical source. The NSA is funding SSC-SD as part of a team, which is employing SSC-SD WDMs in the development of optical signal processors for ultra-wideband signal detection and intelligence analysis. SSC-SD is investigating using WDM technology to upgrade the shipboard GPS fiber optic antenna link and to distribute GPS timing signals throughout the ship to various C4ISR systems. Undersea fiber optic surveillance networks have used fused fiber WDM couplers for distribution of laser signals to fiber optic hydrophones and for data telemetry.

Industry, Academic, and DoD Laboratory Interactions

SSC-SD works closely with industry to develop and apply WDM technology. The WDM couplers used in the fiber gyroscope have been have been developed within the framework of a joint program involving Honeywell International, Draper Laboratories, the Naval Research Laboratory, and SSC-SD. The optical signal processing filters using WDM devices is a joint effort with Photonics Products, Inc. The RF and Photonics Technology Branch of SSC-SD is integrally involved in the DD (X) program in the areas of RF topside design, and this association has led to briefings of the branch's WDM technology to the participants in this program, including the prime contractor, Raytheon. In many cases these teaming arrangements have served to not only introduce the WDM technology to the industry partners, but also have resulted in the identification of specific applications in systems and products of these companies. As a result, many of them have sought to formal acquire the technology through patent licensing

agreements and CRADAs. To date, SSC-SD has executed six patent licensing agreements and concurrent CRADAs involving WDM technology. The industry partners range in scope from small start-ups such as PPI to internationals such as Honeywell and JDS Uniphase.

A.3 Knowledge Web

S&T Project Description

The SSC-SD is developing decision support concepts and tools intended to increase "Speed of Command" and enable collaboration of command echelon decision-makers. At the center of these efforts is the invention of a "Knowledge Web" (K-Web) concept.

The K-Web involves the application of knowledge management practices to warfighting, creating a concept of operations in which value-added information (i.e. "Knowledge") is created and published into a web on the command intranet in real time rather than being coupled to daily briefing cycles. Government-Off-The-Shelf (GOTS) tools have been developed to take the web work out of creating and maintaining the web content. These tools include a template-based authoring tool known as "Summary Maker", and a graphical drawing and annotation tool that creates map-based information products, known as "TacGraph". The tools represent web-enabling technologies that allow information to be used in a manner consistent with a command's current business practices through the development of consistently formatted web pages that are easily authored and published.

The K-Web concept was initially developed for the Global 2000 and Global 2001 Wargames. Based on the utility of the K-Web and supporting tools, COMCARGRU THREE asked that revised versions of the tools be deployed and placed aboard the USS Carl Vinson during their Fall 2001 deployment. SSC-SD, with the support of the Office of Naval Research developed and installed a prototype system aboard the USS Carl Vinson in less than five months.

On September 11, 2001, COMCARGRU THREE assumed command of Task Force 50 in the North Arabian Gulf. As a result, the K-Web was battle-tested by Carrier Group Three during Operation Enduring Freedom (OEF). RADM Thomas Zelibor USN, as COMCARGRU THREE found the K-Web to be a "Powerful" tool in the conducting of OEF, and the entire region came to rely heavily on the products stored in the CARGRU THREE K-Web. Following the return of CARGRU THREE from their deployment, SSC-SD, with ONR sponsorship, has worked closely throughout FY02 with SPAWAR PD-15, CINPACFLT, CFFC as well as with CARGRU ONE and the C3F Network-Centric Innovation Center to migrate the K-Web tools to SPAWAR programs of record, (specifically GCCS-M) and to transition the K-Web to additional battle groups. The K-Web is currently being integrated with the Collaboration At Sea program, and the first release of the production K-Web is being used by the USS Constellation Battle Group during their Fall 2002 deployment, and is planned to support the upcoming deployments of the USS Nimitz and USS Theodore Roosevelt battle groups.

S&T Project Relevance

The Chief of Naval Operations (CNO) has directed that the Navy become "web-enabled" and work towards maintaining "Knowledge Superiority". The latest thrust of this effort is known as "Force Net". The K-Web represents a significant first step in achieving these goals in that it

defines and has demonstrated a significant first step towards a new concept of operations for war fighting. K-Web is explicitly designed to support the distributed collaboration, which is becoming core to modern military operations. K-Web is therefore directly relevant to the efforts of Task Force Web, Force Net, as well as numerous command and control programs including GCCS-M and the Collaboration At Sea (CAS) initiative. .

Industry, Academic, and DoD laboratory Interactions

K-Web has been developed by SSC-SD with the extensive support of Pacific-Science and Engineering Group and Sonalysts, Inc. as contractors. Transition efforts involved the contractual support of DRS Technical Services, Inc., SAIC, Inc, Top Dog, Inc, and other sub-contractors. The K-Web team continues to do research involving the Naval Post-Graduate School, Aptima, Inc., and the Naval War College. The SSC-SD K-Web team continues a long-standing relationship with Dr. Sandra Marshall of San Diego State University developing eye-movement and pupil monitoring technologies as an index of cognitive activity and the development of formal models of decision-making.

A.4 Work of the Applied Chaos and Dynamics Group

Background The Applied Chaos and Dynamics Group (ACDH) is composed of ten scientists and engineers. ACDG maintains strong ties with researchers in nonlinear dynamics from around the world. Distinguished scientists in the field of nonlinear dynamics visit SSC San Diego on a regular basis to collaborate and exchange ideas. The nonlinear research group maintains an excellent scientific record with refereed publications in journals such as *Physical Review Letters*, *Physics Today, and Proceedings of the IEEE.*

S&T Project Descriptions

Nonlinear GPS Antenna

The goal is to develop dynamic nonlinear antennas to combat wideband jamming of Global Positioning System (GPS) signals. By combining recent advances in nonlinear dynamics, active antenna design, and analog microelectronics it is possible to significantly improve signal-to-noise ratio (SNR), frequency locking, and phase locking in the presence of wideband jamming. The project leverages recent advances in active antenna design and the theory of non-identical oscillators to generate beam steering and beam forming across an array of nonlinear oscillators. Additionally, compact arrays, antennas with element spacing significantly smaller than a half wavelength, are possible by directly coupling nonlinear elements. Recent results in the design of compact multi-element antenna arrays demonstrate the importance of the mutual coupling effects between elements upon array performance. This research merges nonlinear dynamics and RF microelectronics to design a new generation of antenna that provide a significant level of directivity and more nulls per wavelength in a smaller volume than conventional approaches.

Advanced Dynamic Fluxgate Magnetometer

The goal of the Advanced Dynamic Fluxgate Magnetometer (ADFM) is to produce a high sensitivity (1-10 Pico Tesla /root (Hz)), but low cost magnetic sensor for use in non-acoustic anti-submarine warfare. The ADFM consists of a standard ferromagnetic core, suitably wound with primary and secondary windings, to measure changes in the ambient magnetic field via output voltage changes. In contrast to the standard Fluxgate operation, the instrument is

configured to take advantage of its nonlinear dynamic properties. Specifically the device is treated as a two-state device. Detection relies on measuring the time intervals between threshold-crossings as the instrument is driven by a known time-periodic signal on which is superimposed the unknown (usually taken to be dc) target signal. In the absence of the target signal, the mean residence times in the two steady states (corresponding to the saturation states in the core hysteresis cycle) are equal on average. However, the presence of the target signal skews the hysteresis loop, thereby introducing a small difference in the mean residence times; this difference is directly connected to the asymmetrizing target signal. Collaborators at the University of Catania, Italy, have an experimental device that demonstrates sensitivity (on the order of 10 Pico Tesla / root (Hz)) and cost about $10 to manufacture.

Baseline Acoustic Sensor Study

The project goal is to produce a *methodology* to compare acoustic sensor performance (both relative and absolute) based on geographic location, environmental conditions, and time of year. Once the baseline performance of the current operational sensors is established, the study will estimate the performance of nonlinear beam forming techniques for use in air-deployed sonobuoys. The simulations are conducted using the established Navy models (e.g., Comprehensive Acoustic System Simulation or CASS), sonar parameters and databases in the PC-IMAT tactical decision aid. The results of simulations are compared to experimental data for validation. A more general study of underwater acoustic sonar performance was performed in 2000-2001 for N77 in the following operational areas of interest: The Straits of Hormuz, Gulf of Oman, Yellow Sea, Sea of Japan, Korea region, China Sea regions, Norwegian Sea, Barents Sea, Straits of Malacca, Straits of Gibraltar, Adriatic Sea and the Cyprus Basin. This study specifically addresses the operational performance of the EER, IEER (with ADAR buoy), 53D, towed array and best air deployed underwater acoustic sensor for specific locations within the study regions. The simulation samples a number of tracks in each region to assess overall performance, as the regions are acoustically diverse both spatially and temporally.

Coupled Inertial Navigation Sensors

The project goal is improving the navigation accuracy of micro electro-mechanical sensor (MEMS) gyroscopes by exploiting coupled, nonlinear oscillator dynamics. The CINS research program utilizes multiple gyroscopes per angular axis with very minimal additional electronics to demodulate the output signal from the array. This is an improvement over previous designs that require a demodulator or other electronics to estimate the angular rotation rate for each gyroscope in the array. This advantage is gained by utilizing a coupling network to synchronize the sense axis displacements of the gyroscopes in the array. The advantages of this approach are the of output signal scales as the number of gyros (when completely synchronization, the noise is averaged prior to demodulation, and only one demodulator is necessary for any number of gyroscopes in the array.

Chaotic Wideband Antenna

This research pursues two complementary themes: the adaptation of control of chaos techniques to develop antennas capable of operating across an enormous bandwidth, and the development of nonlinear antennas incorporating analog signal processing at the plane of radiation collection to perform beam steering and beam forming. To achieve wideband operation of RF oscillators, a new approach in frequency synthesis was developed that uses symmetry braking in coupled

networks of nonlinear oscillators. Under certain conditions, the arrays illustrate periodic behaviors where one array oscillates at N times the frequency of the other array. This type of multi-frequency behavior is different from the one that is observed in periodically forced systems because it is dictated, exclusively, by the symmetry of the network.

S&T Project Relevance

Nonlinear GPS Antenna

The vulnerability of GPS to jamming is well documented. Highly mobile vehicles mounting GPS receivers preclude the use of strongly directive, large aperture antennas to mitigate the effects of jamming. The need for a compact GPS array is particularly important to the F-18 strike aircraft community. Current modernization plans call for the Navy to use a less capable variant of the Air Force's GAS-1 null steering antenna. In order to mount the antenna in less than a 6" diameter space, the Navy variant reduces the number of elements from 7 to 4. This in turn reduces the number of nulling channels available from 6 to 3. The nonlinear antenna project could have a significant impact on compact antenna arrays by allowing the spacing between array elements to be decreased without significantly impacting performance. Typical antenna diversity signal processing algorithms require an element spacing of roughly 10 wavelengths for uncorrelated arrivals. For military frequencies of interest, antenna arrays on platforms cannot support such spacing - e.g., for 1 GHz frequency, the wavelength corresponds to about 1 ft. resulting in about 10 ft. spacing between array elements. However, there are still diversity gains to be achieved even for sub-optimal array element spacing ~ 0.1 of a wavelength. By understanding the nonlinear array dynamics in detail, it may be possible to trade off between amplitude, phase, and coupling parameters to produce a compact array. Beyond the GPS antenna applications include multi-function RF antennas, wideband RF communications, and electronic warfare.

Advanced Dynamic Fluxgate Magnetometer

The ability to sanitize littoral waters of threat submarines is a key challenge facing the Navy. The shallow water acoustic environment is harsh and severely limits the effectiveness of current sonar systems designed for deep water ASW. Key to exploiting non-acoustic signatures for ASW are highly sensitive electric and magnetic field sensors.

Baseline Acoustic Sensor Study

The methodology provided will allow ONR, OPNAV 70, DASN (USW), and the related program offices to make detailed comparisons of sonar systems performance. The methodology will identify the significant processes that limit system performance helping shape the scientific investment, highlight deficiencies in data collection, and ultimately provide a framework in which to test assumptions of proposed acoustic systems.

Coupled Inertial Navigation Sensors

Precision-guided munitions, like the Extended Range Guided Munition (ERGM) and the Joint Direct Attack Munition (JDAM), could benefit from the incorporation of a low cost inertial guidance system that can operate in situations where the global positioning system (GPS) signal is compromised. Current prototype MEMS gyroscopes are compact and inexpensive to produce, but their performance characteristics fail to meet the requirements for an inertial grade guidance

system. Despite the large investment by the Department of Defense, it is unlikely that MEMS gyroscopes will be suitable for inertial guidance systems in the near future. The development of accurate, low cost inertial guidance systems would have immediate uses in gun-launched munitions (ERGM) and other cost and size constrained systems.

Chaotic Wideband Antenna

The Department of Defense recognizes the need for a new generation of advanced antennas for communications and surveillance. In particular, naval combat systems and communications links are transitioning to high bandwidth phased array antennas. In radar applications, the antenna must provide wide instantaneous bandwidth for long range and high-resolution target detection and discrimination, while in C4I systems the twin goals are increased data rates while combining the bands of operation into a single multifunction antenna. High frequency operation, mutual coupling, and high power operation are known to generate nonlinear responses in antenna arrays. Recent research has shown that advanced nonlinear arrays can produce dramatic improvement in signal detection while providing robust operation in the presence of noise, and produce an extremely wide operating bandwidth.

A.5 Robust Waveform Design for Tactical Communication Networks

Background: Recent DoD Technology Area Review and Assessments (TARA) established critical requirements to address the limitations in commercial communications technologies for military applications. The stated concern of the TARA panel was the vulnerability of commercial networks in tactical operational environments where jamming and exploitation are fundamental weapons employed by our adversaries to disrupt critical command and control links.

S&T Project Descriptions. This project develops robust waveforms for use in tactical communication networks that include ship-to-shore, ship-to-air, air-to ground, and terrestrial peer-to-peer communication links. It addresses the special requirements for covert, forward-deployed terrestrial and airborne assets such as unmanned airborne vehicles (UAV), robotic sensors, and ground reconnaissance forces. The tactical mobile radios utilized for such applications have the conflicting requirements of high data rates to transmit video and imagery while remaining in a covert mode to avoid intercept and exploitation by hostile forces.

Candidate waveforms are evaluated on the basis of the fundamental limits of the transmitter/receiver parameters based on information theory bounds and the physical parameters of the channel and the waveform. The focus is on physical waveform characteristics that are robust relative to multi-path fading, amplifier non-linearities, and intentional and non-intentional jamming. Metrics are defined to quantify susceptibility to interception/detection by radiometers and other intercept receivers. The receiver characteristics are optimized for the reception/detection of the selected waveforms.

These results were utilized to evaluate the tradeoffs in data rate and detectability as a function of the physical characteristics of the transmitted waveforms, the communications channel and the receiver/detector. This research effort includes the use of multiple-input, multiple output (MIMO) antennas to further reduce the required energy per bit required to achieve reliable communications. In addition, the susceptibility of these waveforms to hostile interference is being evaluated and techniques to mitigate interference using new nonlinear signal processing techniques are being developed in this program. The 6.1 component of this task has produced

seven published refereed journal papers, six submitted journal papers, fifteen conference papers (two invited), and a book chapter in the past year. Five patent applications are in progress from this effort. The 6.2 component of the effort demonstrated Low Probability of Intercept (LPI)/Low Probability of Detection (LPD) capability during intercept/detection tests at Ford Ord, CA. It was also used to develop an LPD interface to the Extended Littoral Battlespace (ELB) War Net tactical IP network, and LPI/LPD performance was demonstrated in the ELB exercises in Camp Pendelton, CA.

Industry, Academic, and DoD laboratory Interactions.

_ Unfunded Collaborators, * Funded Collaborators, § Transitions Sponsor Collaboration

Industry

- Georgia Tech Research Institute*
- Information Systems Laboratory*
- Hughes Research Laboratories _
- Scientific Applications International Corporation*
- General Electric _
- United Technologies _
- Quantum Magnetics_
- Kearfott Guidance & Navigation Corporation _
- Control-Dynamics.Inc*

Academic

- Georgia Institute of Technology*
- UC San Diego*
- UC Santa Barbara*
- San Diego State University*
- University of Florida _
- Virginia Polytechnic Institute and State University*
- University of Augsburg, FRG _
- University of Perugia, IT*
- University of Catania, IT*
- University of Warwick, UK*
- University of Sussex, UK _
- University of Alberta, CA _

DoD / National Labs / Allied Defense Labs

- NAVSEA Surface Warfare Center, Carderock §
- NAVAIR AIR 4.4T §
- PMA-264 §
- PMW/A-156 §
- National Reconnaissance Office §
- Naval Post Graduate School _
- NASA Glen Research Center _
- Oak Ridge National Lab _
- Lawrence Livermore National Laboratory _
- DARPA §
- FOI (Swedish Defense Research Agency), Stockholm, SE*

A.6 eXtensible Tactical C4I Framework (XTCF)

S&T Project Description eXtensible Tactical C4I Framework (XTCF) facilitates battle space situation awareness and Indications and Warning by providing automated near real-time all-source correlation and fusion of these disparate sources.

XTCF provides the mechanism for transforming the current Joint COE environment by enabling more rapid and timely technical and developmental exploitation of emerging data sources for the next generation Common Operational Picture and C^4I Common Operating Environment (COE). The technical approach for developing this framework will address data source registration, data element registration, data processor/correlator registration, discovery, and data distribution and synchronization.

S&T Project Relevance XTCF addresses the COE TMS limitations and has the following objectives.

- The establishment of a data management framework that enables more rapid and timely technical and developmental exploitation of emerging complex and heterogeneous data sources for the next generation common picture.

- The leveraging of the XTCF data management framework to prove the concept by developing new solutions for existing and new common picture data sources. These solutions will provide both plug-in data representations and single source plug-in correlation mechanisms that will be integrated into the multi-source picture.

- The assurance that XTCF will also continue to support communication and tactical data exchange with the fielded GCCS-M.

Industry, Academic, and DoD Laboratory Interactions Partnerships include: Northrop Grumman IT, SAIC, Maxim Systems, Polexus, Anteon and Delphin. Other commercial companies XTCF has been collaborating with are BEA Systems and Sonic Software (for Message Oriented Middleware), Telelogic (Requirements Management), Orincon (ground moving target indicator system), Alphatec and TASC (frameworks).

Appendix B

List companies with which CECOM-RDEC maintains current SBIR contracts

ATC
Prediction Systems
Enpoint
Foster Miller
Spectra Research
Broadata Comm
Scientific Research
Anntron
Xenotran LLC
Discrete Time Communications
XPRT SOLUTIONS, INC.
Luna Innovations Incorporated
ThinKom Solutions, Inc.
Veros Systems, Inc.
Trident Systems Inc.
Architecture Technology Corp.
WaveBand Corporation
TRLOKOM
Mykotronx
Intelligent Automation
Scalable Simulation Solutions
Coherent Technologies
Digital Optics
Cybernet Systems
Remcom
Idris Communications Inc
Innovative Wireless Technologies, Inc.
Scientific Systems Company, Inc
STAR-H Corporation
Fantastic Data LLC
HYPRES. Inc.
Procito Inc.
Sciperio, Inc.
Moriah Tech

Appendix C

C.1 Examples of RRS projects based on the Adopt/ Adapt approach

In this section a discussion of six representative RRS programs is presented. In each case RRS's emphasis has been upon the approach of adopting existing products, technology and software and adapting them to satisfy the constraints of a sponsored program.
(An apology must be given for the extensive use of commercial acronyms, which have been used in practice so long that they have, in effect, transitioned into nouns or neologisms.)

Joint Defensive Planner (JDP)
The JDP represents the first Tactical Ballistic Missile Control System (TBMCS) application to use the BEA Weblogic application server. The Weblogic product line was segmented for the Defense Information Infrastructure Common Operating Environment (DII COE) and as a result making it available to all DII COE users. JDP also was the first instantiation of 'n-tiered' architecture in TBMCS and the first TBMCS application to run on Oracle 8i RDBMS. The JIntegra Java-COM Bridge was incorporated to allow JDP to export planning tool screens directly into PowerPoint. JDP was the first C2 application in TBMCS to be written in Java.

Broadsword
Project Broadsword uses many open source and government-owned off the shelf (GOTS) products. These include:

- DynaAPI, which is a set of methods that allow JavaScript code to be written in a way that is platform/browser independent
- CGILib, which is a set of libraries designed to allow for the use of a well-formed HTML code
- Falcon View (a GOTS item) uses a GIS Server to support multiple map formats such as Vector, ADRG, CADRG, etc.
- SENDS (GOTS) is used to convert images from TIFF, JPG and NITF formats
- OpenLDAP is used for user Administration/Security
- OpenSSL is used for encryption of information from point to point
- MySQL is used for database storage of audits and transactions

Wireless Information Assurance (IA)
RRS's Wireless IA efforts involved the adoption of commercial WLAN products built to IEEE 802.11b standards and their adaptation so that they could be used safely in the military environment. In addition, RRS wrote a significant part of the new DOD Directive 8100.bb, which now constitutes the ESC/DIG's CITS-Wireless architecture, and the AF's wireless policy. As a result of this activity, RRS, de facto, created the path for the DOD to utilize the commercial technology in a sensible way.

Mixed Initiative Control of Automa-teams (MICA)
The MICA program uses commercial mathematical solving software C-Plex and MAT-LAB for running algorithms within the program development. Draper Laboratory, Alphatech, and the Honeywell Technology Center are the performing activities. The Boeing simulator, designated

as C4ISRSim, was adopted as the central engine for modeling and simulation support system for the Open Experimental Platform (OEP). An RRS supported SBIR Phase II contract with Cybernet Systems called, "The Design of a Graphical User Interface for Managing Multiple UAV's" was built on commercial simulation network software ('Open Skies') and network control technology. It uses graphical methods originally developed for network-based multi-player games. It will be tied into the MICA program.

Bareback

The Garmin Vista firm was tasked to integrate the AN/PSC-11 (PLGR) into the commercial Garmin Vista receiver. The Bareback program requirements are such that the receiver must carry the PLGR due to likelihood that Selective Availability (SA) will not be turned on and other special features that only that unit has. The AN/PCS-11 weighs 10x more, and uses batteries at an 8x higher rate than the commercial unit. The end item deliverable for the Bareback program will have the desirable features of the AN/PCS-11 and the low weight and battery drainage of Garmin Vista's commercial product.

A multiple serial port interface was need for Toughbook (purely commercial item). A 4-way USB-Serial port converter was purchased, and modified it (prototype) to be rugged enough for military applications. A private company was employed to build the serial port converter that did not require additional special cables.

COTS Software & Standards: used a commercial interfacing package to the Comm Ports,
a GOTS math package that does all the applicable geographic transforms (NIMA Approved) two GOTS packages that do all the mapping (PFPS/FalconView and DPSS) use existing NIMA standard products

The program is employing a common framework of TCP/IP and XML (the Navy has already nominated as a draft standard, and the Air Force is working with them to come to terms for a common Schema) allows numerous applications to communicate easily, and makes everyone's work more valuable. It would have been impossible without a common XML schema.

Numerous examples of the adaptation of protocol standards and implementations by the bareback program exist. These include a modified mobile IP to deal with multiple links and mobile networks in addition to leveraged DARPA-sponsored security work

Enhanced Intelligence Preparation of the Battlespace (EIPB)

The Enhanced Intelligence Preparation of the Battlespace (EIPB) program adopted the following Commercial products

- Sybase Database
- Sybase SQS (Spatial Query Server)
- Sun Microsystems Solaris Operating System
- Microsoft Windows 2000 Operating System
- Netscape Communicator (Web Browser)
- Microsoft Internet Explorer (Web Browser)
- Microsoft Outlook E-mail
- Send Mail for Solaris

- Extensible Information System (XIS)
- Sun Microsystems JAVA

C.2 Examples of RRS projects and activities that influence the development of Technology

Participation on Standards bodies
RRS attempts top influence the development of technology by its extensive representation on Standards setting organizations. Once a military or civilian standard is established, all systems both military and civilian) tend to produce systems and products that are compliant. RRS has membership on the following standards setting organizations

- NATO Standard Image Library Interface Technical Support Team
- IEEE Standards Committee, Simulation Interpretability Standards Organization (SISO)
- DASADA support to: OMG, W3C, & ODMG
- Lead, Atlantic PAW Initiative, Multi National WDL Standards for software Defined Radio
- Lead, Software Defined Radio Forum, 120 member standards body for SDR
- Lead, NATO Interoperability ISR Data Links Systems
- AF lead, ATM Over Terrestrial Links Standardization working group

Example of Conference sponsorship
Conference on Infospheric Science Establishing New S&T Beachheads
Where: George Mason University, Fairfax, VA
Date: July 18-19, 2001
Goal: To identify basic science underlying DOD visions of future "infospheres" such as Joint Battlespace Infosphere (JBI), Network Centric Warfare (NCW), Joint Vision 2020 (JV2020); focus on JBI; identify and document basic research issues

Professional activities and memberships of AFRL-RRS personnel that have an influence on the development of technology
IEEE Accreditation Board for Engineering & Technology
Co-Chair of SAF/AQ SIGINT Way Ahead Team
Member of NSA multi-national team for Specific Emitter ID
Associate Editor, International Conference on AI
Vice Chair, AIAA Software Systems Technical Committee
Co-Chair, Defense Adaptive Signal Processing Conference General Chair, IEEE International Conference on Multirate Systems and Wavelet Analysis
IEEE Region 1 Board of Directors
Gordon Bell Award at Super Computing 2000
IEEE Millennium Medal (2000) for Outstanding Achievements and Contribution

C.3 Academic and industrial partnerships and institutes

RRS made clear that much of the effort they lead is undertaken through Academic and Industrial partnerships and institutes. RRS with DARPA support and funding, and with the support and funding of the Air Force Office of Scientific Research (AFOSR) has organized a number of such partnerships and institutes to address specific problem areas in the field of Information Technology. Many of these partnerships and institutes are large. Some appear to have more than 50 University and Industrial members.

Center for Integrated Transmission and Exploitation (CITE)
CITE was established to foster the system-level development of integrated multimedia data analysis and dissemination techniques. It is comprised of a team of in-house government scientists and engineers who work on a collegial basis with teams of scientists and engineer affiliated with:

- Bowling Green State University, where work is underway related to Change points and Adaptive Covariance Estimation
- Hunter College of the City University of NY. Work at this institution is concerned Non-Fourier Transform Domain Analysis
- Texas A&M University. The team at Texas A&M is conducting forefront research related to Scalable Quantum Computing
- Rensselaer Polytechnic University. The group at Rensselaer is engaged in research related to Video Compression and Rate Adaptive Modulation
- The State University of New York at Buffalo. At this institution, Robust Spread Spectrum Receiver Design is being investigated.

The Information Institute (II)

AFRL-RRS in coordination with Cornell University has established the Information Institute. This is an Institute that has been established to act as a focal point of Science and Technology related to Information in the broadest sense of the term. Since the II has been established, it has sponsored a number of workshops on Information Fusion. The II has been the recipient of 4 additional research grants, and recently started a new Multi -University Research Initiative (MURI). In addition to AFRL-RRS and Cornell, a total of 47 Colleges and Universities are associated with the II. The list of affiliated organizations include:

CUNY	Dartmouth College
George Mason University	Illinois Institute of Technology
Iona College	State University College at Farmingdale
SUNY Albany	Binghamton University
SUNY Buffalo	SUNY Institute of Technology
SUNY Stony Brook	Syracuse University
Temple University	Texas Tech University
University of Akron	University of Alabama
University of Arizona	University of Connecticut
University of Hawaii Hilo	University of Kansas
University of Massachusetts	University of Nevada-Reno
University of North Dakota	University of Rochester
University of Virginia	Utica College of Syracuse University

Wright State University
Monmouth College
New York Institute of Technology
Ohio State University
Purdue University
Rochester Institute of Technology
Sacred Heart University
AF Academy
AFRL /IF
Carnegie Mellon University
Clarkson University
Cornell University
Louisiana State University
Nassau Community College
Oakland University
Penn State University
Rensselaer Polytechnic Institute
Rutgers University
Southern Polytechnic State University
AFIT
Alabama A&M
Central Michigan University
Columbia University

The Information Assurance Institute

RRS management has entered into a MOU with Cornell University to establish The Information Assurance Institute (IAI). This institute has a presence at both the Cornell campus and at the AFRL Rome Research Site. This arrangement allows AFRL-RRS personnel to participate in research projects at Cornell and reciprocally it allows personnel from Cornell to address AFRL-RRS projects. The advantage to Cornell is that it provides Cornell students and faculty members with access to some unique facilities that are available at the RRS and to RRS personnel who are leaders in the field of Information Assurance. A total of 10 research efforts have been funded through IAI.

The Intelligent Information System Institute
Intelligent Information Systems Institute (IISI)
Technology "Theme Controlling Computational Cost Information Capture and Discovery from linked heterogeneous information sources [new initiative, 2002], Pervasive computing: autonomous distributed agents and communication networks." Advanced Computing Architectures Funded 13 Research Projects.

C.4 R&D Teams for specific mission problem areas

RRS has formed four large teams, composed of personnel from University, Industrial and Governmental Agencies. These teams were organized to provide focused attention in the areas of, Ground Moving Target Exploitation, Information Assurance, The Joint Battlespace Infosphere, and High Performance Computing.

Ground Moving Target Exploitation (GMTE)
The objective of the GMTE R&D team is to develop an enhanced operational capability to exploit MTI data automatically in order to locate, identify, and track high value ground moving targets. The achievement of such a capability requires progress in many areas. A need exists for a Common GMTI format and for multi-platform automatic tracking and registration. A need also exist to be able to catalog databases in real time. The team is attempting to develop improved capabilities to analyze and understand the motion and behavior patterns of ground moving vehicles. The team is also studying the implications of advanced radar modes on air to ground weapon delivery. Resource allocation and scheduling algorithms are being developed so the use

of resources may be optimized to allow the timely engagement of ground moving targets Automatic sentinels are also being developed so that operator-specified movement events will be triggered. Other areas of the team's interest include the problem of fusion information derived from multiple sources, the development of algorithms for the optimum scheduling of sensor resources and the employment of sensors in move-stop-move operations. Finally the team is working on the time honored problem of the integrated employment of ISR assets

The GMTE R&D Team has 26 Industrial partners including:

Black River System Corp	Syracuse Research
Boeing	Modern Technology Solutions
TRW	Harris
Zel Technologies	Alphatech
Atlantic Aerospace	Veridian
Mission Research	Toyon
Pacific Sierra Research	Orincon
ERIM-International	Lockheed Martin
AETC	SAIC
VTI	Emergent IT
Computer Science Corp	Integrated Sensors
MITRE	Northrop-Grumman
Raytheon	General Dynamics

The GMTE R&D Team 's Academic Partners include Colorado State University**,** the University of Connecticut, and the University of Buffalo. The GMTE R&D Team's Government partners include representation from ESC/JS, PM/CGS and ONR.
Coalition Partners associated with the GMTE R&D effort include the UK, Germany, France, Norway, Italy, and Canada.

Information Assurance R&D Team
RRS has established an R&D team to focus on the extraordinarily important issue of information assurance. The objective of this team is to develop improved techniques for the protection of networks and computers against attacks. The team's efforts are concentrated on the detection of attacks and on an analysis and response to computer and network attacks. An effort is being undertaken to integrate the techniques of defensive and offensive information warfare. The team's objective is to provide more secure survivable networks for and classified traffic needed for Joint/Coalition operations. The overall objective of the team is to provide enhanced Information Assurance for embedded systems. RRS has recruited a large team of participants from industry, academia and government.

The 23 industry participants on the Information Assurance R&D Team include:

BBN	Kestrel Institute
Odyssey Research	CYCORP
Orincon	Sarnoff Corp
SCC	Teknowledge
Boeing	SRI International

Software Engineering Inst.	Computer Science Corp
Logicon	GITI
Intellitactics	PRC Litton
SAIC	Solsoft
NAI Labs	Reliable Software
Net-Squared	Wetstone Tech
General Dynamics	

There are 13 Academic organizations that are represented on the Information Assurance R&D Team. These include:

Cornell	Utica College
MIT/LL	UC Berkeley
USC	U Mass
Georgia Tech	Dartmouth
Princeton	Stanford
Johns Hopkins	George Mason Univ.
Arizona State	Carnegie Mellon Univ.
Drexel	

The Information Assurance R&D Team also is supported by representatives of two international bodies (TTCP and NATO), two operational commands (PACOM and SPACECOM), three DoD agencies (NSA, DISA and AF/AIA), an federal contract research center (IDA) and the National Institute of Justice (NIJ).

The Joint Battlespace Infosphere (JBI) R&D Team

The current focus of the JBI R&D team is the integration of commercially available enterprise management, middleware into the JBI. The intent is to develop JBI performance metrics or measures of effectiveness along with the development of a JBI core service (e.g. Publish/Subscribe/Query). The team is also attempting to validate all new JBI components for inclusion into JBI spirals.

The Joint Battlespace Infosphere R&D Team includes the following 17 industrial and FFRDC participants.

MITRE Corp. (FFRDC)	Boeing
Charles River Analytics	Schwalb Consulting LLC
Litton-PRC	MITRE Corp.
Oracle Corp.	META Group
ISX	Motorola
Reliable Network Solutions	Orielle
Alphatech	Progeny
GITI	Teknowledge
MCNC	

In addition to the 17 industrial and FFRRDC participants, the Joint Battlespace Infosphere R&D Team profits from the participation of the following 12 Universities and Colleges.

Cornell	UC Boulder
UVA	Hamilton
Carnegie Mellon Univ.	North Carolina
JHU / APL	UCLA
Stanford	Wright State
LSU	USC / ISI

Finally the Joint Battlespace Infosphere R&D Team profits from the participation and attention of the following 17 Government organizations.

AFRL/XP/HE	ESC
AC2ISRC	C2 Battlelab
AF/SC	AMC
AFOSR	ONR
JIVA PMO	HPCMP
DARPA	SPAWAR
NWDC	NavAir
SOUTHCOM	PACOM
JFC / JBC	

High Performance Computing (HPC) R&D Team

RRS management has considered the implications of the continued effect of Moore's law. Even if Moore's law hits a 'knee in the curve' within the next 5 to 10 years the computing power measured in billions of floating point operations per second per million dollars of cost (flops/$M), should by the year 2010 approach 360 trillion flops/$M. This will represent a significant advance relative to the capabilities of contemporary computers. Realization of the potential of such computing power will require new approaches to computing and software development techniques. In anticipation of this issue, RRS management has organized a broadly based R&D team to address the issues inherent in High Performance Computing. The HPC team has encouraged strong participation by Academia, Industry and Government.

The R&D team for High Performance Computing enjoys the participation of representation from the following list of 39 Universities.

Boston University	Brigham Young
Brown University	Caltech
Carnegie-Mellon	Case Western
Clemson	Columbia
Duke	Georgia Tech
Johns Hopkins	Mississippi State
MIT	NYU
Northwestern	Ohio State
Princeton	Purdue

Stanford	UC - Berkeley
UCLA	UC – Irvine
UC - Santa Barbara	Univ. of Cincinnati
Univ. of Colorado	Univ. of Delaware
Univ. of Illinois	Univ. of Maryland
Univ. of Michigan	Univ. Notre Dame
Univ. of Pennsylvania	USC
Univ. of Tennessee	Univ. of Texas
Univ. of Utah	Univ. of Washington
Univ. of Wisconsin	Vanderbilt
Virginia Polytechnic	

The capabilities of the R& D team for High Performance Computing also profits from an equally impressive team of industrial participants composed of representatives of the following 17 companies, National Laboratories and FFRDCs:

Altera	Applied Photonics
ARMA	The Athena Group
Atlantic Aerospace.Emergent	General Electric
Hewlett Packard	Honeywell
IBM	Irvine Sensors
ITT	JPL
Lawrence Livermore	BAE Systems
Computer Sciences Corp	Coventor
DSA	

C.5 Listing of US Information Technology companies that have performance contracts with AFRL-RRS

List of Information Technology companies that have contracts with RRS in the dollar range between $20 and $75 million:
GTE Govt. Systems
BBN Corporation
Synectics Corp
Logicon, Inc.
PRC Inc.

List of Information Technology companies that have contracts with RRS in the dollar range between $10 and $20 million:
Sterling Software
Northrop Grumman
Sterling IMD, Inc.
SRI International
Motorola, Inc.
TRW, Inc.
Trusted Information Sys

List of Information Technology companies that have contracts with RRS in the dollar range between $5 and $10 million:
Alphatech, Inc.
Science Applications Int.
Global Infotek, Inc.
McDonnell Douglas Corp
Kaman Sciences Corp
Raytheon Company
Sales Engineers, Inc.
Boeing Company
Teknowledge Corp
Lockheed Martin
Rome Research Corp
Eclectic Computing Concepts
GDE Systems, Inc
Honeywell, Inc.
Decision Science Applications
Bell Communications
PRB Associates
Syracuse Research Corp
Grumman Aerospace/Data Sys
ISX Corporation
Pacific-Sierra Research Corp
Kestrel Institute
Research & Development Labs

List of Information Technology companies that have contracts with RRS in the dollar range between $1 and $5 million:
Computer Sciences Corp
Raytheon E-Systems
Orincon Corp
Call/Recall
Calspan Corporation
HRL Laboratories
Bellcore
Martin Marietta Corp
Sanders-Lockheed
IIT Research Institute
Secure Computing Corp
Logicon Eagle Technology
E-Systems
Rockwell Science Center
Tektronix Federal Systems
The Analytical Sciences Corp (TASC)
CYCORP

List of Information Technology companies that have contracts with RRS in the dollar range less $1million:

CACI Technology Services
Open Software Foundation
Scientific Research Corp
Research Associates of Syracuse
Integrated Sensors, Inc.
Booz, Allen & Hamilton
Intel Systems Technology
Object Services & Consulting
Litton Systems, Inc.
Viasat, Inc.
General Electric Company
Texas Instruments, Inc.
Eastman Kodak
Harris Corporation
Raytheon TI Inc
Odyssey Research Assoc.
Matercraft Industries, Inc.
IET, Inc.
Giordano Automation Corp
PAR Govt. Systems
Draper CS Laboratory
Technology Service Corp
Fuentez Systems Concepts
INCERT Software Corp
Physical Optics Corp
Stiefvater Consultants
Sensor Com, Inc.
Betac Corporation
Microelectric & Comp Tech
Modine Mfg. Co.
General Dynamics Advanced
MCNC
IS Robotics
Cogentex, Inc.
ENSCO, Inc.
Systems Research & Appl.
Lucent Technologies
MYRICOM, Inc.
Research Associates for Def.
Information & Extraction
Telemedia Research
Opticomp Corp.
Focused Research

Reliable Software Tech
Lockheed Electronics
MAYA Design Group
GEC-Marconi Hazeltine
ERIM

Appendix D

Project level examples of NRL's interactions with IT organizations in Industry and Academia. In anticipation of the visit of the Study Team, the ITD furnished Study Team members with 58 examples of individual ITD projects that pointed out specific interactions. In this Appendix, 15 examples are provided. For each example only the project description and interaction section is presented.

D. 1 Language Understanding for Interactive Knowledge Management (PI: Elaine Marsh, Co-PI: David W. Aha)

S&T Project Description

Navy operational experiences and knowledge contained in text documents are significantly underutilized due to inadequate structure and their resulting inaccessibility to advanced computing and reasoning methods. We are investigating how structuring text documents can improve the accessibility to their knowledge content. This structuring, we conjecture, will also enable content reorganization and presentation to suit specific decision support needs of users. To this end, we are developing and evaluating natural language methodologies, tools, and lexical resources to semantically enhance and enrich text knowledge sources into structured actionable knowledge repositories. Another line of our research is focusing on the development of techniques for guided retrieval of enriched knowledge that tailors itself to the user's competency and need.

Industry, Academic, and DoD laboratory Interactions

We are the leading researchers in the area of conversational case-based reasoning (CCBR), and our research from this project has been published in international CBR conferences (e.g., ECCBR'02, ICCBR'01). We have transitioned our Taxonomic Case Retrieval System (TCRS), a state-of-the-art CCBR tool, to universities and industry partners. TCRS is being applied to workflow management by researchers at the University of Innsbruck, Austria. CDM technologies, of San Luis Obispo, CA, a DOD contractor is applying TCRS to assess ship readiness. The technology transfer to CDM technologies has taken place under our CRADA. Intelligent Automations Inc, Rockville, MD, is applying TCRS to tutorial design in a SBIR project.

We have demonstrated the effectiveness of our Acronym Extraction tool (AcE), an outcome of our information extraction research, to several DOD organizations on their documents, including: NWDC, Providence, RI, and the USAF Doctrine Center (AFDC), Maxwell Air Force Base, AL. We have interacted with Georgia Tech Research Institute, Atlanta, GA, concerning our lesson retrieval methodology

D.2 Interoperable Networks for Secure Communications (INSC) (PI Joseph Macker NRL)

S&T Project Description

Research teams at the Naval Research Laboratory and SPAWAR Systems Center San Diego are serving as the U.S. component of an eight-nation consortium that is developing an interoperable

network for secure communications (INSC). INSC is a technology application and development project which will demonstrate an interoperable, manageable, and secure military inter-network over various military and civil networking infrastructures, including mobile networks, based on existing and emerging standards, commercial services and products. The INSC work represents the culmination of progress achieved in several earlier Navy and international network-technology development efforts. The work will enhance the Navy's capability to field the communications network architectures needed to conduct network-centric warfare—a top line fleet goal.

Industry, Academic, and DoD laboratory Interactions

The INSC project is a collaborative activity between Canada, France, Germany, Italy, Netherlands, Norway, United Kingdom, and the United States, with participation by NATO C3 Agency. The INSC MOU has been completed and was approved by the final nation in February 2001. This effort is 6.2/6.3 jointly funded with Navy IPO providing the 6.3 funds and ONR providing the 6.2 funds.

While participating broadly at the architectural level in helping to formulate project direction and tasking, NRL (Joe Macker) is also acting as the International Task Leader in the area of mobile wireless networking. Multinational cooperative research and experiments are being performed much of which is based upon NRL technology efforts resulting from ongoing and past R&D efforts. Joe Macker (NRL) also serves as liaison within the Internet Engineering Task Force, the primary Internet standards body.

D.3 Vision System (PI: Frank Pipitone)

S&T Project Description

Technology has been developed which can automatically recognize objects based on their surface shape, resulting in two U.S. patents. This can be used on a wide variety of spatial scales, encompassing a wing nut and a plane fuselage. The object is recognized in milliseconds, in arbitrary pose and in extreme clutter, with high confidence, and the six coordinates of its pose are returned. There are two components, a range imaging scanner, called the Correlation Scanner, which creates a depth map accurate to 100 microns at low cost, and an algorithm called Tripod Operators for surface shape recognition and localization. These results grew out of 25 years of work directed at providing high performance machine vision for robots.

Industry, Academic, and DoD laboratory Interactions

NRL has a CRADA with Ford, Perceptron et al, to transition and demonstrate NRL technology in Detroit. NRL also has a MOA with The Walter Reed Laboratory related to range imaging. NRL representatives have participated in many Navy-Industry Conferences related to this area.

D.4 Co-evolving Cooperative Behaviors for Teams of Autonomous Vehicles (PIs: Mitch Potter and Alan Schultz)

S&T Project Description

Autonomous systems must exhibit appropriate high-level behaviors to perform a desired task. In well-structured domains with little uncertainty, such as an assembly line, these high-level behaviors can be hand-designed using control theory. However, this is not practical if the autonomous system must operate in unstructured and uncertain environments, robustly adapt to changing external conditions, and tolerate partial system failures. Evolutionary computation is proving to be well suited to the design of behaviors for autonomous systems operating in these more challenging environments. However, to effectively co-evolve cooperative behaviors for multiple autonomous robots, we must understand the power and tradeoffs associated with alternative behavioral representations. The technical objective of this project is to identify specific problem-domain characteristics that give one representation an advantage over another.

Industry, Academic, and DoD laboratory Interactions

An informal relationship has been established with a professor at Swarthmore College that led to joint research and publication directly related to this project. Funding is being provided to a Ph.D. student at George Mason University who is investigating the co-evolution of rule-based representations. Both PIs are co-chairing the evolutionary robotics program committee of the 2003 Genetic and Evolutionary Computation Conference. One PI is chairing the Second International Workshop on Multi-Robot Systems, which brings together top multi-robot researchers from around the world. Both PIs review evolutionary computation and robotics papers for a variety of international journals and conferences.

D.5 Multicast Data Transport Research (PI Joseph Macker)

S&T Project Description

NRL ONR-sponsored 6.2 research project has developed technology for reliable dissemination of network multicast data. In addition to performing research, NRL has designed and developed working prototype software models for both simulation and real world environments.

Industry, Academic, and DoD laboratory Interactions

NRL is actively involved in commercial standards transition for this technology area. NRL was a prime contributor in Internet Research Task Force investigations and is presently leading Internet standardization efforts based upon present work outcome. This activity serves to transition findings directly to broad industry components. Technical papers describing research contributions have been published and academic work has built upon NRL findings and prototype software. The present NRL working prototype, the Multicast Dissemination Protocol (MDP) has transitioned into many operational systems and experiments in cooperation with other organizations.

Within the DoD, NRL worked with CECOM and TRW to integrate NRL MDP software into the Force XXI Battlefield Brigade and Below (FBCB2) system, a core Army battlefield communication system. NRL worked with SPAWAR San Diego to help transition MDP software to both submarine and fleet communication systems presently being fielded. The software is also being used in coalition experiments to support group situational awareness improvements. NRL also worked with the US Postal Service (USPS) and industry partners to deploy MDP within a nationwide USPS V-SAT multicast network. The system provides tremendous cost saving and allows previously unachievable widespread updating of clerk

terminal software at Post offices. NASA, in cooperation with NRL, is using MDP in the "Internet in Space" program and a NASA technical team recently demonstrated a shuttle experiment on ST-107 using NRL software.

D.6 Safehost (PI: John McDermott)

S&T Project Description

The Safehost project applies special-purpose hardware, host-based intrusion detection technology, and cryptography to the problem of malicious software that tampers with mobile agents and network management software. The project is building exploratory prototypes and investigating basic principles related to high-assurance protection of mobile software agents and remote services from tampering.

NRL is applying for a patent on the product of this research. We anticipate that some forms of this mechanism will be licensed in products produced by industry.

Industry, Academic, and DoD laboratory Interactions

Specific details of this work have been communicated to NSA under a nondisclosure agreement, and cannot be discussed here. The Principal Investigators are familiar with related work by Microsoft (Palladium), the Trusted Computing Platform Alliance, and University of Cambridge Computer Laboratory (Ross Anderson). NRL is applying for a patent on the product of this research, and anticipates that NSA will license some forms of this mechanism and incorporated into products produced by industry for the DoD.

D.7 Security Assurance and Navigation Environment (SANE) (PI: Judith Froscher)

S&T Project Description

The SANE project is developing tools for visualization and management of *assurance arguments* for complex large-scale systems. Assurance arguments organize the evidence used to certify or accredit the security of an information system. Security certification (or accreditation of a specific system) must consider operational use, physical security, personnel, and other factors as well as technical security built in to the target system. Many of these issues cannot be modeled mathematically, but impact the mathematical or technical assurance that is built into an information system. Assurance arguments are currently handled by manual means.

Industry, Academic, and DoD laboratory Interactions

SANE is targeted at both Navy activities like SPAWAR and commercial information security companies like Promia. The SANE assurance argument methodology influenced the structure of the Common Criteria for Information Technology Security Evaluation (ISO 15408). Promia has begun informal discussions with NRL regarding application of the SANE tool set to the certification and accreditation of the Naval Intelligent Agent Security Module (NIASM). Promia initiated the relationship based on the reputation of early prototypes of the SANE toolset.

NRL 's Principal Investigators, have coordinated their assurance argument work with Carnegie Mellon's CERT research group

D.8 Project Title: Prototyping the Global Grid Vision

S&T Project Description: Broadband communications is a critical pillar of the Department of Defense's means to provide a global information infrastructure. This information infrastructure is daily relied on to meet the current and projected needs of the Department for achieving "information dominance." NRL plays a pivotal role in setting and rapid prototyping the 'global grid' vision that builds a "network-centric" future for the DOD, IC and civilian systems. Global Grid today melds advanced fiber-optic networks in the ground with mobile connectivity into the theater and to/from sensor platforms to provide global, assured communications for the warfighter and all their supporting elements. NRL is currently on the path to scale the 'global grid' vision one/two orders of magnitude to include advanced satellite communications and high performance distributed supercomputing seamlessly into the infrastructure.

Industry, Academic, and DoD Interactions: NRL has worked collaboratively with academia through DARPA/NSF/DOD/NASA in implementing the "Global Grid" vision through partnering with programs: i.e., the Strategic Computing Program (SCP), High Performance Computing and Communications (HPCC), the Next Generation Internet (NGI), and the High Performance Computer Modernization Program (HPCMO); standards bodies (IETF, ITU, SPMTE) to implement needed features to normalize global use of encryption at the National Level and to support protection of intellectual property through peer-to-peer authentication with Kerberos, both in the network control plane through SNMP and for use in authentication to assets. Work with the Intelligence Community has evolved 'key-agility' to the forefront as the technology of choice for all DoD, IC and Coalition(NATO) interaction. Lastly, too numerous to name, are the smaller startups that have spun out of this vision to establish them in the marketplace.

D.9 Dynamic Access for Satellite-Based Networks (PI:Michael Rupar)

S&T Project Description: The technical objective of this program is to develop a Dynamic Access capability for a satellite-based network to effectively plan and manage SATCOM resources. Dynamic Access can be defined as a process of using application-layer and instantaneous network traffic characteristics to dictate the usage of physical layer (the satellite bandwidth) assets to a particular node in the network. It consists of the control techniques, processes, and procedures over networks, terminals, satellites, and up/down-links to effectively plan, monitor, control, and configure/reconfigure those assets in instantaneous dynamic response to user priority and utilization while optimizing the overall throughput of the system.

Industry, Academic, and DoD laboratory Interactions

NRL is currently collaborating with Loral-Skynet, one of the leaders in satellite services in the world. NRL has developed a test and evaluation plan in coordination with Loral-Skynet engineers to assess and check our efforts to accurately measure, quantify and allocate satellite transponder resources in a dynamic fashion. NRL has a CRADA with Loral-Skynet to develop advanced communications technologies and methodologies.

NRL is also coordinating its efforts with the ADNS community at SPAWAR PMW-179, and has generated great interest by the Navy Warfare Development Command (NWDC) at the Naval War College in Newport, RI. NRL participates in meetings of the Transformational Communications Architecture, to ensure that any developments of this program will be applicable to future Navy satellite communications.

D.10 Composable Mission Space Environments (PI: Philomena Zimmerman)

S&T Project Description

The Composable Mission Space Environments (CMSE) project focuses on the problem of rapidly composable, valid simulation environments, and the issue of total interoperability within distributed Modeling and Simulation (M&S). The goal of this project is to examine the current state of the art for M&S composability and to determine what is relevant for each M&S functional area. Additionally, for items not immediately applicable to DoD M&S, identify where there is value added in pursuing the technology. The primary outputs of this project are standards, processes, and data that are broadly applicable within DoD M&S, and may be applicable outside of DoD. At the very least, this project will foster collaboration between DoD and its Service components to enable true, rapid, and valid M&S interoperability.

Industry, Academic, and DoD laboratory Interactions

This effort would be futile if done in a vacuum. Since inception in 2002, the funding source has been the Defense Modeling and Simulation Office (DMSO), an OSD office within the AT&L chain. The lead for this effort (NRL PI) is provided to DMSO through a MOA. Research efforts within the program are conducted by NRL, Universities and Government Laboratories (e.g. Johns Hopkins University Applied Physics Laboratory, Virginia Modeling Analysis and Simulation Center at Old Dominion University, Argonne National Laboratory, Air Force Research Laboratory, Idaho Department of Energy), Federally Funded Research and Development Centers (e.g. RAND, Software Engineering Institute at Carnegie Mellon University), and contractors (e.g. Gard Associates, SAIC, Inc., ALION Inc., Virtual Technology Corporation, AegisTG, JRM Associates, EnvoyTek, Pitch AB from Sweden, MaK Technologies, Visitech).

Additionally, the Service M&S offices provide regular input to a variety of issues, and provide efforts for validation of products and software proof of concepts. To ensure that the widest possible collaboration occurs, this program is working with IEEE Computer Society sponsor committees, Simulation Interoperability Standards Committee (chair)) Learning Technologies Standards Committee (member), Simulation Interoperability Standards Organization, NATO Modeling and Simulation Group, and informally with other government agencies, such as National Institute of Standards Engineering and Manufacturing Laboratory, and OSD T&E Common Test and Evaluation Improvement Program office.

D.11 Integrated Autonomous Vehicles (PI: Alan Schultz)

S&T Project Description

This project contributes toward the design of future autonomous systems by extending recent results in the area of machine perception, behavior-based control architectures, dynamic autonomy, human-robot interactions, and machine learning, with a focus of innovative designs for integrating these functional capabilities. The systems under development are designed to work in situations involving multiple robots and humans in competitive or cooperative tasks. Key research has been in the areas of advanced, natural interfaces between humans and autonomous vehicles that combine speech, gestures and hand-held computing devices, the use of

computational cognitive models as reasoning modules for autonomous vehicles, and adaptation to failures in the vehicles capabilities and to changes in the environment.

Industry, Academic, and DoD laboratory Interactions

- Close association with Carnegie Mellon University's (CMU) Robotics Institute, widely regarded as the top robotics research facility in the world. Joint project with CMU, Northwestern University, Swarthmore College, and Metrica Corp. Also have close associations with George Mason University, Georgia Tech (Ron Arkin), University of Pennsylvania's GRASP Lab (Vijay Kumar), and University of South Florida (Robin Murphy).
- Good interactions with key robot manufacturers including iRobot and Nomadic Technologies. CRADA with Nomadic Technologies allowed exchange of source code and access to proprietary code.
- PI is sole U.S. Representative to NATO working group on "Multi-Robots Systems in Military Domains." NRL hosted 2002 meeting and is hosting second meeting in 2003.
- PI is Organizer and program chair of First International Workshops on Multi-Robot Systems.
- PI is Deputy Program Manager of Intelligent Autonomy product line of the Autonomous Operations Future Navy Capability; strong interactions with PMS-403 and PMA-263. The FNC is developing products for unmanned air, ground and undersea vehicles.
- Army Night Vision Lab – Distributed navigation and human-robot interaction software to allow them to quickly get up to speed on their research
- Department of Energy, INEEL, is paying NRL to integrate NRL technology into robots for inspection of contaminated spaces.
- NASA JSC. Major participant in Robonaut project, sponsored by NASA and DARPA. NRL-developed software for multi-modal human-robot interfaces will be used on this humanoid robot.
- Informal interactions with the Northrup-Grumman Advanced Technology Lab on intelligent autonomy techniques. Includes information exchange and writing of joint proposals.

D.12 Voice Biometrics (PI: George Kang)

S&T Project Description

Voice biometrics is the technology to authenticate speakers using individual voice characteristics (rather than using passwords or cipher locks) to control access of information, computers, facilities, and weapon systems. This S&T project has three objectives:

- Develop a voice biometrics device which is more reliable in performance and user-friendly (i.e., quick to verify speakers – within two seconds)
- Test and evaluate commercial voice biometrics devices operating in 9 different Navy platform noises with 6 different vocoded speech inputs.

- Test and evaluate remote voice biometrics over existing secure voice communication links where the information source and speaker are not co-located

Industry, Academic, and DoD laboratory Interactions

Currently, the Navy is performing five biometrics tasks. NRL is coordinating voice biometrics tasks with the Navy (SPAWAR Systems Center Charleston) and with John's Hopkins University/APL. In addition, a member of the International Telephone and Telegraph Company (ITT) is implementing the NRL's high-level language software to operate in real-time by PC.

D.13 Composing Requirements Specifications (PI: C. Heitmeyer)

S&T Project Description

An important issue in developing the Navy's mission-critical systems is how to specify and analyze the large and complex requirements of these systems. One promising approach is to decompose the requirements into components, specify the components, and then compose the component specifications to produce the complete requirement specification. However, using this compositional approach requires the solution of two
problems: 1) parallel composition of components may result in circular feedback loops, and 2) proof is required that the composite system satisfies its specification if each of its components satisfies its specification. While the handling of feedback loops has been largely ignored, significant research has been done on compositional proof techniques by Pnueli (1984), Abadi and Lamport (1990), Henzinger et al. (2000), and others. This project is investigating two problems: 1) how to adapt and extend compositional proof techniques to the composition of requirements specifications and 2) how to specify feedback loops without introducing circularity. Our approach is to develop compositional techniques using the formal requirements model that underlies the SCR (Software Cost Reduction) notation. A case study based on the CARA (Computer-Assisted Resuscitation Algorithm), part of the infusion pump under development by the Walter Reed Army Institute of Research, will be used to demonstrate and evaluate our techniques.

Industry, Academic, and DoD Laboratory Interactions

This case study is a joint effort between NRL, researchers and developers at the Walter Reed Army Institute of Research, and a small company called Wisdom, Inc. In this project, NRL scientists and engineers are also interacting with Paul Jones from the FDA (Food and Drug Administration), who plans to transfer the technology and methods developed in the project to the developers of commercial medical devices. They are also interacting with their peers from the Univ. of Pennsylvania, the State University of New York at Stonybrook, and North Carolina State University who are also using the CARA infusion pump as the basis for case studies of their technology. The Univ. of Pennsylvania has included NRL's tools in the suite of tools that they are using in their case study of CARA.

D.14 Voice Gateway (PI: Thomas Moran)

S&T Project Description

The NRL Voice Gateway is a prototype communications platform that ties multiple tactical radios together with commercial telecommunications systems. The main objectives are to:

- Provide access to tactical, secure voice radios from ISDN and VoIP terminals.
- Create a smooth upgrade path for various legacy secure voice radios.
- Provide secure communications across commercial telecommunications networks and equipment to tactical radios.

Industry, Academic, and DoD laboratory Interactions

NRL has been supporting SPAWAR in a SBIR contract that parallels its own efforts. This SBIR contract funds Scientific Research Corporation (SRC) of Atlanta, GA to develop a multicast IP security package over which NRL's tactical VoIP application can be run. In addition, L3 Communications has expressed interest in NRL's tactical VoIP application in order to supplement the capabilities of their MARCOM switch. NRL is currently having meetings pursuing these ends. NRL is also involved in DISA's planning efforts for incorporating VoIP into the DSN.

D.15 Human Centered Scientific Visualization (PI: Greg Trafton)

S&T Project Description

NRL is exploring how scientists understand, comprehend, and use complex visualizations. NRL has developed a novel theoretical framework (spatial transformations) and have applied it to a wide variety of visualizations (scientific, meteorological, etc.). The NRL developed theory is able to make predictions not only about whether one visualization is better than another is, but also how to improve those visualizations to make them more useful to scientists and engineers.

Industry, Academic, and DoD laboratory Interactions

This project has extensive interactions with other military, academic, and industry institutions. NRL has formal interactions with the University of Washington, NUWC, SPAWAR, the University of Pittsburgh, George Mason University, and several METOC offices. NRL has established MOUs with NAVPACMETOC to help facilitate these collaborations. Several government labs (Sandia, NUWC), companies (Microsoft), and top-tier academic institutions (Carnegie Mellon University, MIT) have used NRL's spatial transformation framework to evaluate their own interfaces and visualizations. The PI was recently asked to present part of this work at several national and international conferences (for example, a NATO meeting on visualization), have participated regularly in visualization and diagrammatic conferences and workshops, have been a program committee member of several conferences, and review multiple journal papers on visualization. These activities not only keep NRL informed of others' work, but they allow other researchers and engineers to see NRL's prominence in this area.

Alan Berman received his Ph.D. from Columbia University in 1952. From 1952 until 1967 he worked at Columbia University's Hudson Laboratories. He served as Director of Research of the Naval Research Laboratory from 1967 until 1982. From 1982 until 1987 he was Dean of the Rosenstiel School Marine and Atmospheric Sciences of the University of Miami.

From 1987 until 1995 he served as a Fellow, of the Center for Naval Analyses (CNA) where he had responsibility for the analysis of: Navy R&D investment programs, space operation capabilities, information operations, and C4ISR programs. In 1995 he became a part-time employee of both CNA and the Applied Research Laboratory Pennsylvania State University.

He has served on numerous studies and panels of the Defense Science Board, the Naval Research Advisory Committee, the Naval Studies Board and the Army's Science Board. In 1996 he was appointed as a member of oversight board of the Jefferson Laboratory of the Department of Energy.